SIEMENS

SIMATIC APT

Applications Manual

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⚠ DANGER

DANGER indicates an imminently hazardous situation that, if not avoided, will result in death or serious injury.

DANGER is limited to the most extreme situations.

⚠ WARNING

WARNING indicates a potentially hazardous situation that, if not avoided, could result in death or serious injury, and/or property damage.

⚠ CAUTION

CAUTION used with a safety alert symbol indicates a potentially hazardous situation that, if not avoided, could result in minor or moderate injury.

CAUTION

CAUTION used without the safety alert symbol indicates a potentially hazardous situation that, if not avoided, could result in property damage.

NOTICE

NOTICE indicates a potential situation that, if not avoided, could result in an undesirable result or state.

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Preface

Purpose of This Manual

The *SIMATIC APT Applications Manual* is intended to help you design and write an application program for controlling a factory process using APT. You will find programming hints, specific examples, some philosophy about designing the controls for a factory process, and several executable demonstration APT programs.

New Features of APT

The capabilities of APT have been enhanced in Software Release 1.9A. The documented differences between APT Release 1.9 and Release 1.9A are indicated by change bars in the manual page margins.

Controller Families

APT continues to support two controller families, the Series 505 and the SIMATIC S5. Most programming tasks, like writing a program, downloading, or debugging, are handled the same way in APT regardless of your controller type. The way APT treats direct memory addressing and I/O is determined by whether you have an S5 or a Series 505 controller.

How to Use This Manual

This manual has been arranged into four major sections.

- Section One (Chapter 1) presents a strategy that you can follow when you design an application program. This strategy is general enough to be followed no matter what tool you use to write the program. APT is, however, assumed to be the programming tool.
- Section Two (Chapter 2) describes several specific APT program applications. The examples exist on the distribution media for APT Software Release 1.9A.
- Section Three consists of four chapters. Chapter 3 contains APT programming hints. Chapter 4 includes some suggestions on handling controller memory. Chapter 5 introduces you to a commercially available program language that can be used to create a dynamic simulation for testing the APT program. Chapter 6 provides information for configuring an S5–155H redundant controller system using APT and COM 155H.
- Section Four consists of one chapter and three appendices. Chapter 7 provides information on how to use APT to configure your SIMATIC OSx operator interface database. Appendix A explains how to determine the controller address of an object. This information is necessary when you are creating a database for a OSx or non-OSx operator interface. Appendix B shows the extensions that are fixed by the compile for OSx tags that you have marked. Appendix C shows the information that is translated to OSx for each APT object.

Checklist

In order to take advantage of the example programs described in Chapter 2, we suggest that you have the following hardware and software.

- Software release 1.9A of the Application Productivity Tool — APT.
- IBM or compatible computer with an 80486 or Pentium processor with an EGA, VGA, or CVU graphics card.
- A SIMATIC 545, 545L (545 Lite), 555, 565/565T/565P, or 575 controller, or an S5 Programmable Controller with a 928B, 948, or 948R CPU. See the APT Installation Appendix in the *SIMATIC APT User Manual* for cable pinouts and communication link options.

The Other Manuals

This manual is not intended to be a primer on programming. If you are not familiar with the techniques of programming with APT, refer to the other manuals in this set:

- *SIMATIC APT User Manual* is a guide for using the operator interface to enter your program.
- *SIMATIC APT Programming Reference (Tables) Manual* and *SIMATIC APT Programming Reference (Graphics/Math) Manual* provide the information that you need to design your process control solution. These manuals describe the APT programming languages, the characteristics of APT objects, and the tables that you use to configure these objects. Information is presented in the order that provides for the most efficient and logical design of an APT program.
- *SIMATIC APT MAITT User Manual* provides the information that you need to design and execute a test program for an application program.
- *SIMATIC APT Release Notes* have important information not included in the manual set.
- The APT manual set is available both in paper form (APT–8200–T) and in electronic form on CD-ROM (APT–8200–CD).

NOTE: Unless otherwise specified, the term “OSx” is used throughout this manual to designate SIMATIC TISTAR Releases 1.x and 2.x in addition to SIMATIC PCS Release 3.x and SIMATIC PCS 7 OSx Release 4.x.

Chapter 1

Approach to APT Program Design

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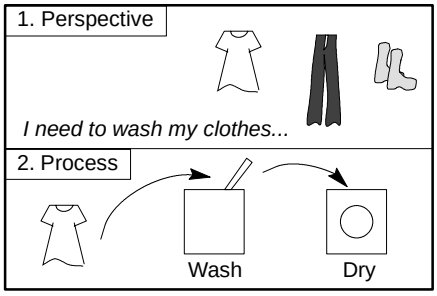
1.1 What This Chapter Presents

This chapter discusses a method for designing a process control application program. There are many ways to approach the problem. The procedure summarized below is a proven method that leads to a well-structured and easily maintained program. The most important concept to remember is that a well-designed control solution is structured and modular. A well-designed system is structured using an approach called top-down analysis, and is executed using a methodology called bottom-up implementation.

The following general topics are discussed in this chapter.



1. **Develop a perspective for the process.** Examine the process in its entirety and understand the equipment involved. View the process as a system, and understand the role of all the major processing components (such as reactors, distillation columns, weighing systems, mixers, packaging systems, etc.). Identify equipment that is, or may become, a shared resource. For example, a weighing system can be shared by several mixers.

Determine whether or not you can follow a distributed approach or you need to use a single controller. If a single control node approach is followed, address the problem of capacity. What happens if the solution grows to exceed the capacity of the controller? Will the solution be distributed easily to multiple control nodes, or will a major effort be required? Determine if a potential for future expansion exists. Consider the possibility that the products made in the process will change over time to include new or expanded product lines.

All the above considerations should be addressed in the initial structuring of the problem. Planning for expansion and growth in the initial design leads to a flexible, expandable and often more understandable design solution.

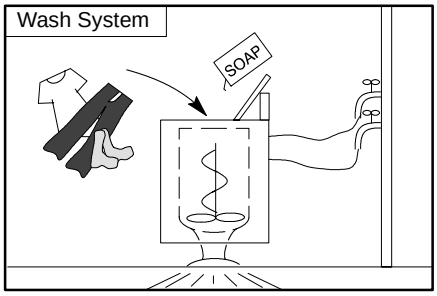
2. **Do a top-down analysis.** Break a system down into a hierarchical set of functional subsystems. Control strategies such as temperature control or pressure control are at the lower levels in the hierarchy. The goals are at the highest levels: “The requirement is to wash and dry 220-pound loads of clothes each week, in five eight-hour shifts”.

Starting with the requirements, your process-design team develops a physical and operational solution to the problem. The process-automation engineer puts a control solution in place to enable the system to achieve the stated process objective. The automation engineer needs to do a top-down analysis of the process from the viewpoint of process automation.

In this phase your design team is attempting to understand and develop a systems view of the process. A top-down analysis looks at the process and attempts to answer these questions first: (1) What are the major process steps involved in producing a product or family of products? (2) What role does the process equipment play?

After the major process steps are identified, analyze each of the major equipment areas and break them down into the essential processing steps involved. Next break down each process step into its components. Finally, analyze the various components of each process step and look for possible further sub-division.

In this step, focus on the tasks that you need to do. Do not be overly concerned with the details of how to do them.

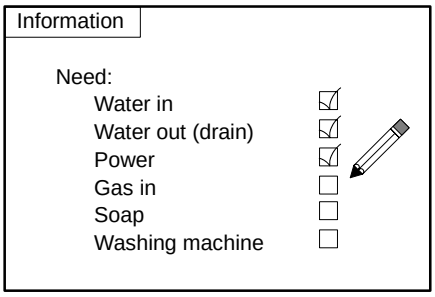


3. **Do a bottom-up implementation.** This is the step in which you address the details. Bottom-up implementation is the process of developing the code for the functional subsystems identified in the top-down analysis phase, starting at the lowest level in the hierarchy: the I/O subsystem.

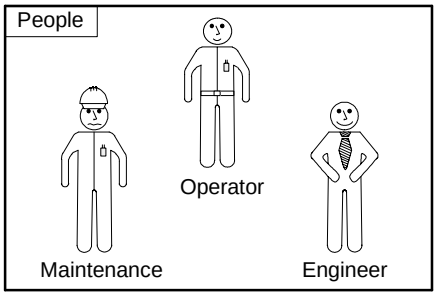
These are the actual programming and configuration steps involved in program development. These tasks range from assigning the symbolic names to equipment to configuring the operator interface and merging all aspects of the design control solution. Develop the program incrementally, and test it thoroughly at each stage of development.

1.2 Develop a Perspective for the Overall Process

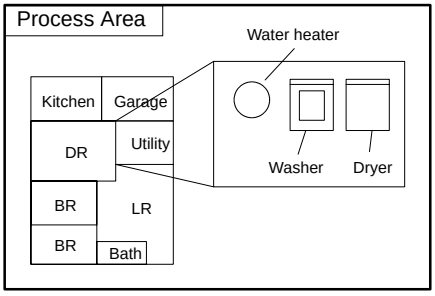
When you develop a perspective of a control problem, you develop a clear understanding of the process and its operation. This phase of the design process includes the following considerations.



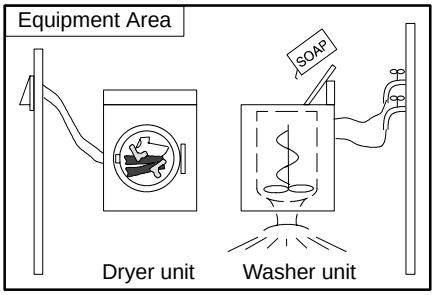
Information. Collect all the relevant information that you need for a thorough understanding of the project, such as batch logs, P&IDs, functional specifications, operator station requirements, I/O lists, etc.



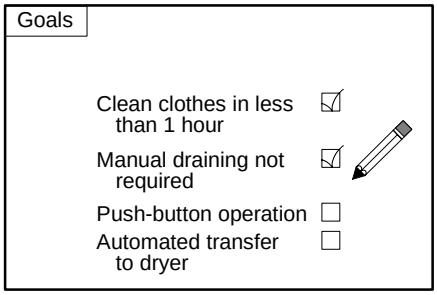
People. Get all the interested parties involved in the planning stages: the project engineer, representatives from management, testing personnel, the operator station graphics designers. You also need to include the process operators. These people are the final customers, the ones who need to be satisfied in order for the process control to run smoothly after startup. Understand that the people most affected by the solution (Operations) are the ones who are often the most unwilling to get involved at this stage. However, for a process retrofit these are the people with the most knowledge about how the process actually runs.



Process area. Be certain that you know the area of the factory for which you are planning a control design. Are you working on a plan for the entire factory, or a portion of it? Exactly what are the boundaries to your portion of the process?

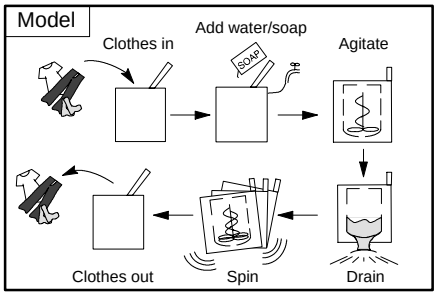


Equipment areas. Identify the major areas to be included in the design. As you determine these areas: weighing systems, blenders, packaging systems, boilers, etc., you are also partitioning the process into more manageable units. Equipment areas represent major processing equipment, not operational tasks such as Clean-in-Place (CIP). The CIP often includes multiple equipment areas and should be viewed as an operational mode.



Goals. Identify the goals of the control system.

- You want to design an efficient and effective means of producing a product.
- The process needs to produce a variety of products.
- The design solution must be flexible.
- The operator must be able to advance to the next process step easily.
- The operator must be able to abort a batch.



Model. Develop and maintain an internal operations oriented model of the system. Be able to state in simple language what the system is supposed to do from the viewpoint of process operation. If you are unable to explain it easily to another person, you might ask yourself if you really understand it. Keep in mind the next two steps, top-down analysis and bottom-up implementation.

1.3 Do a Top-Down Analysis

At this stage of process control development, you are concerned mostly with a system view of the process. However, be able to change your focus readily from the system view to a more detailed view so that you can anticipate and avoid as many problems as possible.

A design engineer who designs physical process equipment for a plant must subdivide the facility into functional units, such as mixers or reactors. Each unit is designed as an independent entity, but with an underlying consideration for the process as a whole.

As a control engineer, you can use the same tactic when designing the solution to a process control problem. You can follow a structured, modular approach by dividing a large control design problem into smaller, more manageable sub-systems. You design each sub-system independently, keeping in mind the needs of the system as a whole, and then integrate the separate results to provide the total design solution.

A systematic procedure that has worked well for Siemens Energy & Automation engineers who have designed and developed process controls includes the elements described below.

Consider the Whole Problem, Then Subdivide

Partition the process into units. Try to divide the process along lines that represent the functional organization of the physical plant. Then plan to dedicate one independent section of the application program to each equipment area. When you partition a system, you are promoting understanding as well as allowing for expansion.

Always think in terms of function when you choose the partitions. Do not allow the physical size of the equipment, or its representation on the P&ID, influence your decisions about partitioning. For example, a piece of equipment may be so complicated that it is drawn on a single sheet of the P&ID. This does not necessarily mean that you dedicate an APT unit to control that equipment. It may functionally belong within another unit.

In the event that the equipment serves as an independent supplier to several other units, function may dictate that you control this equipment through its own independent APT unit.

You can improve the organization of your control program by partitioning the process by function, not by task. The simple process shown in Figure 1-1 is partitioned by function and by task to show the difference.

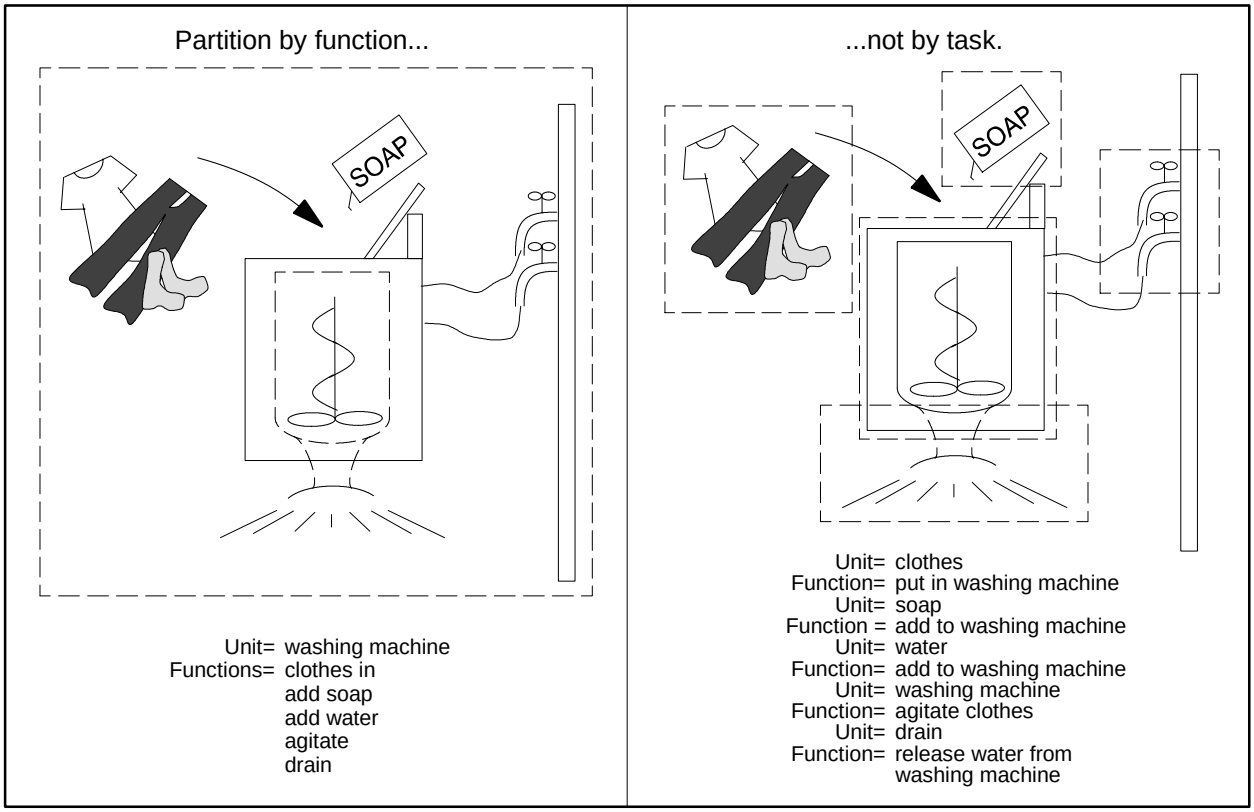


Figure 1-1 Partitioning by Function or by Task

Identify interconnectivity among the equipment areas. Within each partition, note which pieces of equipment are to be shared by different areas. These items are shared resources and are termed global because access to them is required in other equipment areas, beyond the immediate equipment area.

Improper or task-oriented partitioning results in the incorrect inclusion of many global objects in the system. A common mistake is to make all I/O and devices global due to uncertainty about which objects are needed by a unit. This approach results in a system that is less maintainable and expandable.

Consider this: It is easy to move the small number of objects that are truly global but mis-identified as local. It is more difficult and time-consuming to move the massive number of truly local variables from global to local equipment areas.

Do a Top-Down Analysis (continued)

Determine What the Process Does

Ascertain the upper-level tasks that the process must do. Do not be overly concerned with the details or how they need to be handled. For example, consider the equipment functions in a laundry room.

Two operations comprise the process of washing clothes: a wash operation and a rinse operation. The following phases are common to both operations: fill, agitate, drain, and spin. The four phases execute in both the wash and rinse operations. The add soap phase is unique to the wash operation.

You also need to consider operations other than just the wash and rinse operations. Will the system have to handle delicate clothes differently from normal loads of clothes? Will permanent press cycles be included? Will the system handle large, medium, small and extra-small loads? All these considerations can affect the complexity of the control solution.

The wash operation consists of the following steps: fill, add soap, agitate, drain, and spin. The rinse operation consists of these steps: fill, agitate, drain, and spin. The primary differences among process cycles consist of cycle duration, water levels, and strength of agitation.

A well-planned design differentiates the common process steps from the unique ones. The common process steps are the building blocks for the total control solution.

A poorly-planned design treats each phase in each operational mode as unique. This design approach requires more coding and debug effort. Also, problems and errors typically have to be corrected in more than one place. This leads to potential long-term problems.

Determine How the Process Is To Be Done

At this stage you want to determine the high-level requirements of the tasks identified in the previous step. The analysis at this stage is intended to determine the essential elements of the task.

Consider the laundry room example again (Figure 1-2). The fill phase adds water to the tank up to a predetermined level. The add soap phase meters a predetermined quantity of soap into the washer. The agitate phase runs the washer's agitator for a predetermined length of time. The drain phase pumps water from the washer. The spin phase runs the spin motor and injects water into the system during the initial phase of the spin phase.

Each of the previous statements represents a high-level description of the task without specific details as to what is involved in accomplishing the task. For each phase, you need to specify functional requirements. For example, consider the fill phase.

First, determine whether the system will provide a single level, several levels, or a continuous range of level settings. For a flexible system you may provide the operator a switch setting for selecting high, medium, low, and extra-low water levels. This switch setting will be used to determine the level setpoint for the fill phase. At this stage, however, the only requirement to consider is whether one or multiple level settings is required.

The temperature of the water in the washer will also be determined by the fill phase. A common washer design includes a simple solenoid valve for hot water and one for cold water. In this system, the fill phase will manipulate the hot and cold water valve to provide both level and temperature control.

The essence of the fill phase is to open the correct combination of water valves and wait for the level to reach the specified setpoint. When the level has been achieved, the water valves shut down automatically.

You should analyze each of the other phases similarly.

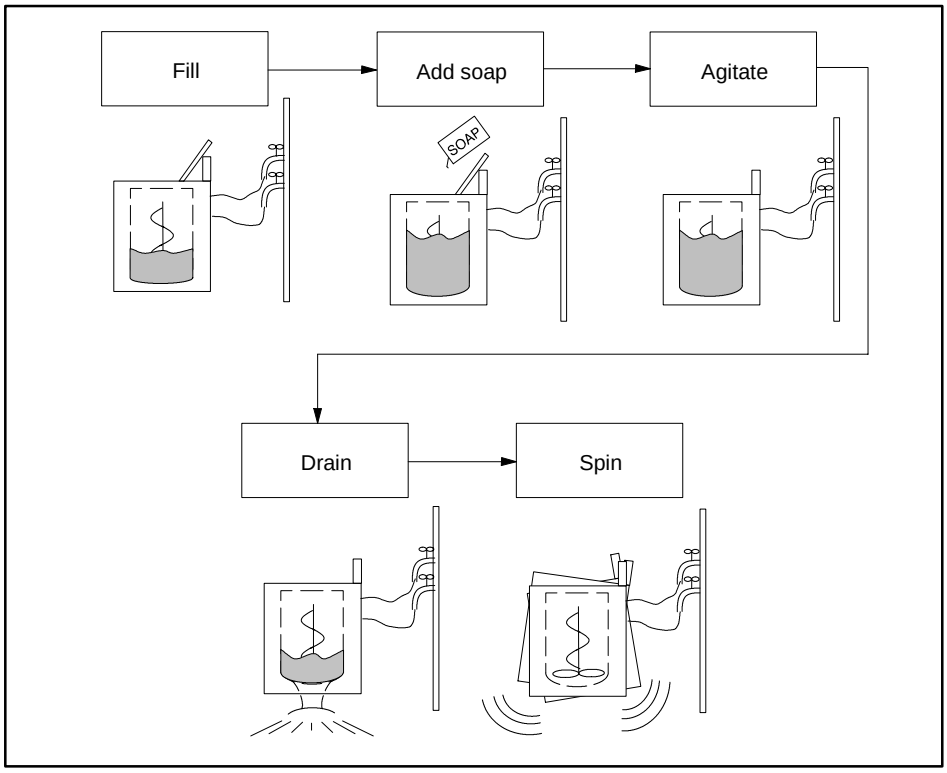


Figure 1-2 Determine the Process Tasks

Do a Top-Down Analysis (continued)

Determine Control Needs

Identify the kinds of continuous control needed, and which safety interlocks are required. Examples of continuous control include temperature control or a mass totalizer in a batch reactor. An example of an interlock is a provision for shutting down the water valves if the tank is full. Another interlock could stop the spin motor if the washer lid is open.

Define what sequential procedures need to be used in conjunction with the continuous control. For example, the mass totalizer would be used in the fill phase of a chemical reactor.

Example: Mental Exercise for Top-Down Analysis

In order to develop a working internal model of the system, consider the following example. The objective is to assign to yourself the task of task-master/manager and to delegate all the other tasks. The example is built around the washer example, and the task-master/manager will be the master washer. Keep in mind the following considerations.

- Suppose that you had a large number of people whom you could ask to run your process (Figure 1-3). You can employ as many as you like; however, they are not free. They must be paid, which means there is a cost to using them in your process. Also consider that a diverse mixture of skills and abilities is available for you to utilize. Some of the people are good supervisors and coordinators; others perform detailed tasks well. Each skill level has a certain cost. Take care to match the skill level to the task.

- Consider the laundry room example again. The washing machine has valves and motors that need to be controlled and monitored. Control of a valve is a mundane and rote task, but one which requires attention to detail and obedience. The task of master washer, on the other hand, requires the ability to work with others and to coordinate their activities. Skill with detailed tasks is less important. You are wasting valuable resources when you select a master washer to handle valve control, or select a valve controller to do wash coordination.

An efficient, cost-effective and understandable organization designed to execute the task of washing clothes consists of valve/motor controllers, a level controller, a temperature controller, a tank filler, an agitator, a drainer, a spinner, a soap dispenser, and a master washer who coordinates the total wash activity. A safety team, which ensures the safety of the overall operation, is also needed to work in conjunction with the wash team. The safety team has the passive role of monitoring conditions until a fault occurs that demands immediate action. When called to action, the safety team works primarily with the valve/motor controllers to ensure the safe shutdown of the washer system.

This exercise is simplistic, but may give you ideas to consider as you study the control design for your process. It can help you identify the tasks that make up a process, determine the process partitions, and to develop a feel for what the process is supposed to do.

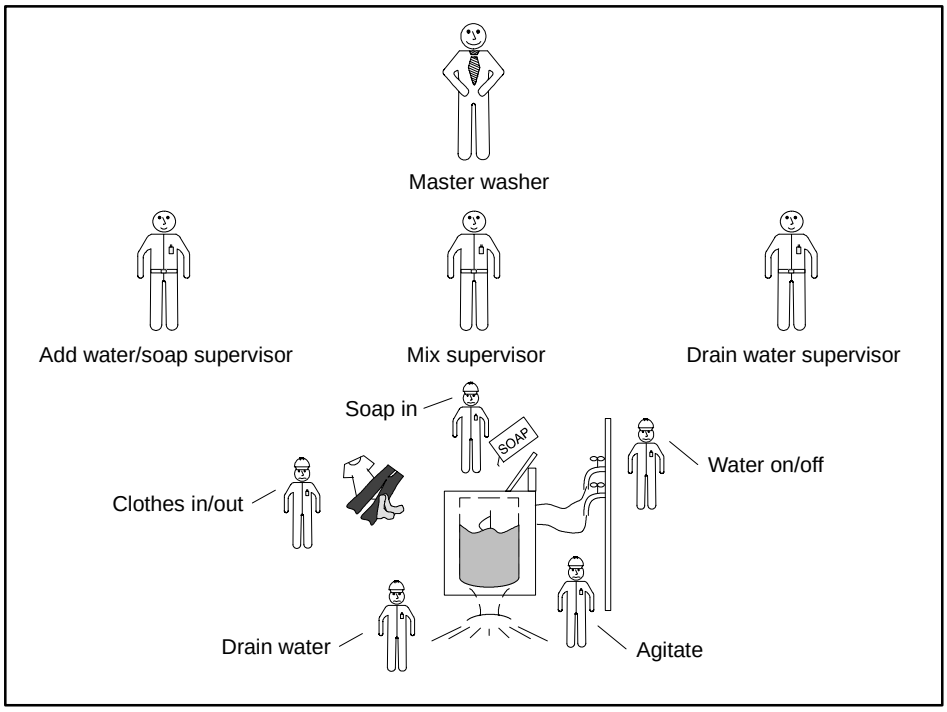
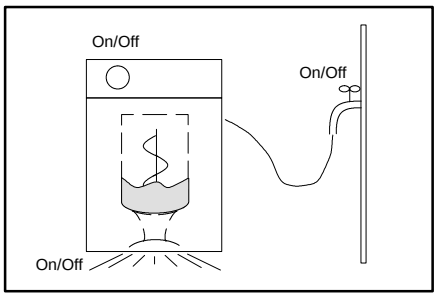


Figure 1-3 Example of Control Determination

1.4 Plan the Bottom-Up Implementation

Use a Layered Approach

The bottom-up implementation consists of doing all the related tasks concerned with designing and creating the application program. Approach the design as a series of levels with a number of layers within each level. Level and layer are defined as follows: A level represents the degree of automation for a process, ranging from operator control to full automatic control. A layer represents the tasks that you have to complete in order to bring a process to a certain level of control.

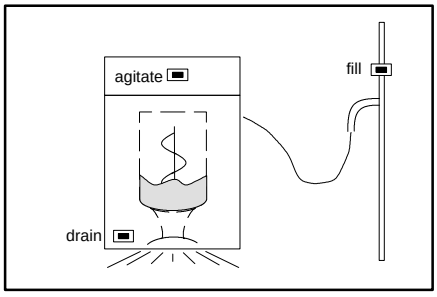


Level 1 At Level 1 control, the degree of automation is such that the operator can manipulate the control system easily. Safety protection logic has been incorporated into the process, and continuous control logic is in place. At the operator station, the operator must manually operate devices, modify loop modes and change set points in order to run the process.

The system is ready for loop testing, PID tuning, and physical equipment testing. You need to verify that an operator can successfully monitor and control the process from the operator station, through the controller, to the field equipment.

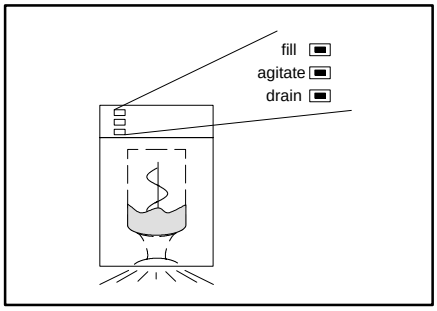
In the laundry example, you have a washing machine that requires considerable manual control. The water valves are connected but you open and close them manually. The agitator can operate, but you must start it and stop it. You must also start and stop the drain pump and spin motors.

Level 2 A process at Level 2 has operational goals imposed on a Level 1 process with a simple operator interface structure. Your prerequisites for the development of a process to Level 2 include a sequence list of defined procedures, an execution order for the procedure, and a formula recipe list. As control development proceeds, the process advances through three states: Procedural, Structural, and Objective Control.



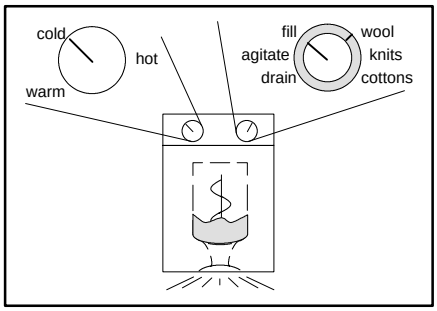
Procedural Control. Basic control procedures are defined. You concentrate on developing the set of operational procedures that perform specific functions when activated by a higher level of control. Procedures include tasks such as Fill Tank, Agitate, Drain Tank, etc. You have two priorities for procedural control: the procedure does the assigned tasks correctly, and the procedure operates independently and potentially in parallel with all other procedures.

In the laundry example, your goal is to design a procedure which responds to a discrete signal, such as a pushbutton, to begin operation. When this procedure has finished, it turns on another discrete signal. For example, the Fill procedure begins when a pushbutton is pressed, and illuminates a lamp when filling is finished.



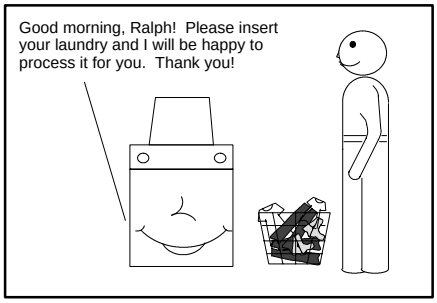
Structural Control. You plan the flexibility for the system structure. A very rigid system has a fixed and definite execution pattern. A flexible system has an open data-driven pattern. For this reason, a flexible data-driven design is recommended. Consider this: you can build a rigid system from a data-driven pattern, but you cannot build a flexible system that is based on a rigid structure.

In the laundry example, each of the operational phases is independent and can be executed at any time with a pushbutton when procedural and structural controls are in place. Interlocks are in place to prevent certain phases from executing simultaneously, such as Fill Tank and Drain Tank.



Objective Control. You impose a data-driven execution pattern upon structural control. The process operation becomes essentially automatic, subject to operator intervention, and has the full flexibility offered by many recipes.

In the laundry example, you select the wash cycle that drives the various procedures, Fill, Agitate, etc. You can select from one or more wash cycles, start the washing machine, and leave, knowing that when you return the clothes will be washed.



Level 3 A process at Level 3 control has been developed and improved thoroughly. All necessary and desired refinements, e.g., report design, operator help screens, etc. have been added. Level 3 control may be an ongoing process that extends beyond initial commissioning.

Layers. There is a set of related tasks that, logically, you need to do first. This set of related tasks comprise a layer in the level of control defined above. Each task in the layer represents a degree of accomplishment. When you complete the first layer of tasks, you proceed to subsequent logical groups of tasks, or layers, until the process control design is finished.

Figure 1-4 illustrates the levels and layers that make up the bottom-up implementation. Layers of tasks represent more and more structure and increasing dependency upon lower layers of design to function correctly. The addition of each layer adds more automatic controls and, consequently, less reliance on an operator to handle control functions.

Figure 1-4 shows how the levels of control change as you proceed in the development of your program. Note, however, that as you climb the stairs that represent each layer of tasks, your progress is not strictly linear. Typically, you must do some backtracking, and translate tags again, or program some more continuous control after having worked on structural control, for example.

As you work on each layer of tasks, never lose sight of the top-down goals and the associated internal model described in Section 1.2. Continue to partition your work. Divide a problem into small sub-problems, or modules, that can be addressed independently and systematically. This will enable you to minimize the number of complex issues to be dealt with at any point in the design cycle.

Sections 1.5–1.13 of this chapter describe the tasks in detail and give you some suggestions about how to do them. You can create any application program by following the order in which they are presented.

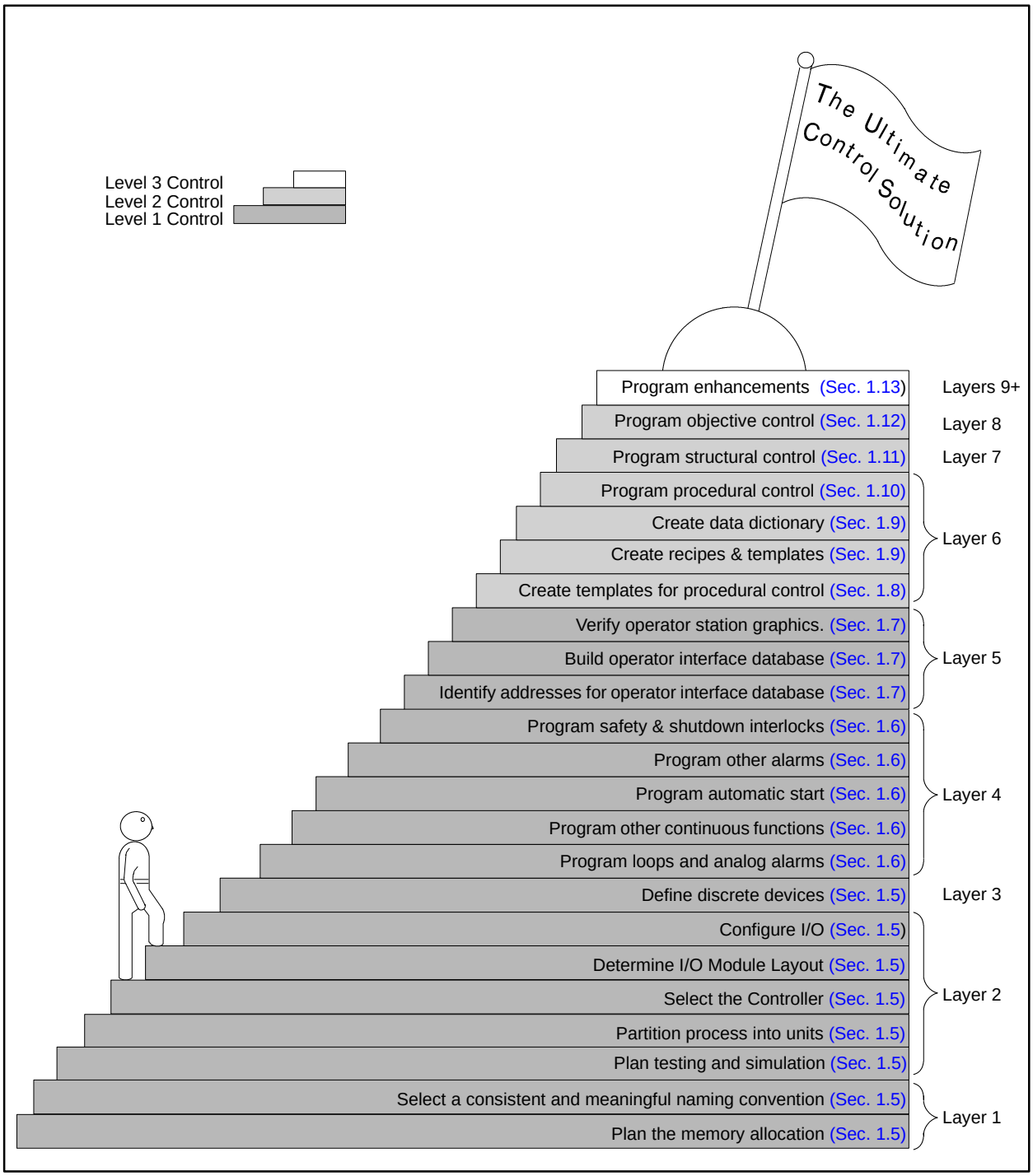

Level 3 Control
Level 2 Control
Level 1 Control
The Ultimate Control Solution
Program enhancements (Sec. 1.13)
Program objective control (Sec. 1.12)
Program structural control (Sec. 1.11)
Program procedural control (Sec. 1.10)
Create data dictionary (Sec. 1.9)
Create recipes & templates (Sec. 1.9)
Create templates for procedural control (Sec. 1.8)
Verify operator station graphics. (Sec. 1.7)
Build operator interface database (Sec. 1.7)
Identify addresses for operator interface database (Sec. 1.7)
Program safety & shutdown interlocks (Sec. 1.6)
Program other alarms (Sec. 1.6)
Program automatic start (Sec. 1.6)
Program other continuous functions (Sec. 1.6)
Program loops and analog alarms (Sec. 1.6)
Define discrete devices (Sec. 1.5)
Configure I/O (Sec. 1.5)
Determine I/O Module Layout (Sec. 1.5)
Select the Controller (Sec. 1.5)
Partition process into units (Sec. 1.5)
Plan testing and simulation (Sec. 1.5)
Select a consistent and meaningful naming convention (Sec. 1.5)
Plan the memory allocation (Sec. 1.5)
Layers 9+
Layer 8
Layer 7
Layer 6
Layer 5
Layer 4
Layer 3
Layer 2
Layer 1

Figure 1-4 Tasks Comprising the Bottom-Up Implementation

Study the Example Program *WASH_DEM* for Series 505 Controllers

The example program *WASH_DEM* illustrates the concepts that are emphasized in this chapter. If you load it on your system, you can follow along with the control strategy. To install *WASH_DEM* follow these steps.

1. Insert the APT software CD in your CD-ROM drive; or, if you created diskettes from the CD, insert DISK8 in your diskette drive.

2. Ensure that the current DOS "path" environment includes the path to the APT executables directory. For example, if APT is installed at D:\APT, enter the following command:

   ```
   PATH
   ```

   If D:\APT is not included in the list output by `PATH`, add it by entering the following command:

   ```
   PATH=%PATH%;D:\APT
   ```

3. If you are loading the example program from the CD, enter the following command, substituting your diskette drive for E, and your disk drive containing the APT database for D:

   ```
   E:\DISK8\LOADDEMO  E:\DISK8\WASH_DEM  D:
   ```

   If you are loading from diskette, enter the following command, substituting your diskette drive for A, and your disk drive containing the APT database for D:

   ```
   A:\LOADDEMO  A:\WASH_DEM  D:
   ```

The APT database is typically on the drive where you installed the APT software, unless you selected the **Configure Directories** option during installation or reconfigured your system at a later time.

If you have configured APT so that the APT software is installed on multiple drives and/or in non-standard directories, then you must ensure that the environment variables APT_DB and APT_COMMON exist and are assigned appropriate values. APT_DB specifies the path to the APT database and APT_COMMON specifies the path to the directories FORMS, LIB505, LIBMC5, and TEXT. If these environment variables are not set and you know the correct values, you can set them.

For instance, consider that the APT executables are in D:\APT, the database is in C:\DATABASE, and the TEXT directory is in E:\APT. As above, ensure that the PATH includes D:\APT, and then set the other environment variables by entering the following commands:

```
SET APT_DB=C:\DATABASE

SET APT_COMMON=E:\APT
```

If you are loading from CD drive G, enter the following command:

```
G:\DISK8\LOADDEMO  G:\DISK8\WASH_DEM
```

If you are loading from diskette drive B, enter the following command:

```
B:\LOADDEMO  B:\WASH_DEM
```

To install the other example programs, substitute the program names (*APT_SIM*, *FOOD545N*, *HX_DEMO*, or *WASH_S5*) for *WASH_DEM*.

Plan the Bottom-Up Implementation (continued)

Coordinating With Operator Interface Design

On the left side of Figure 1-5 you can see a list of the typical tasks involved in creating a process control program. The right side includes the tasks involved in creating a corresponding operator interface. Ideally, you do these two sets of tasks in parallel.

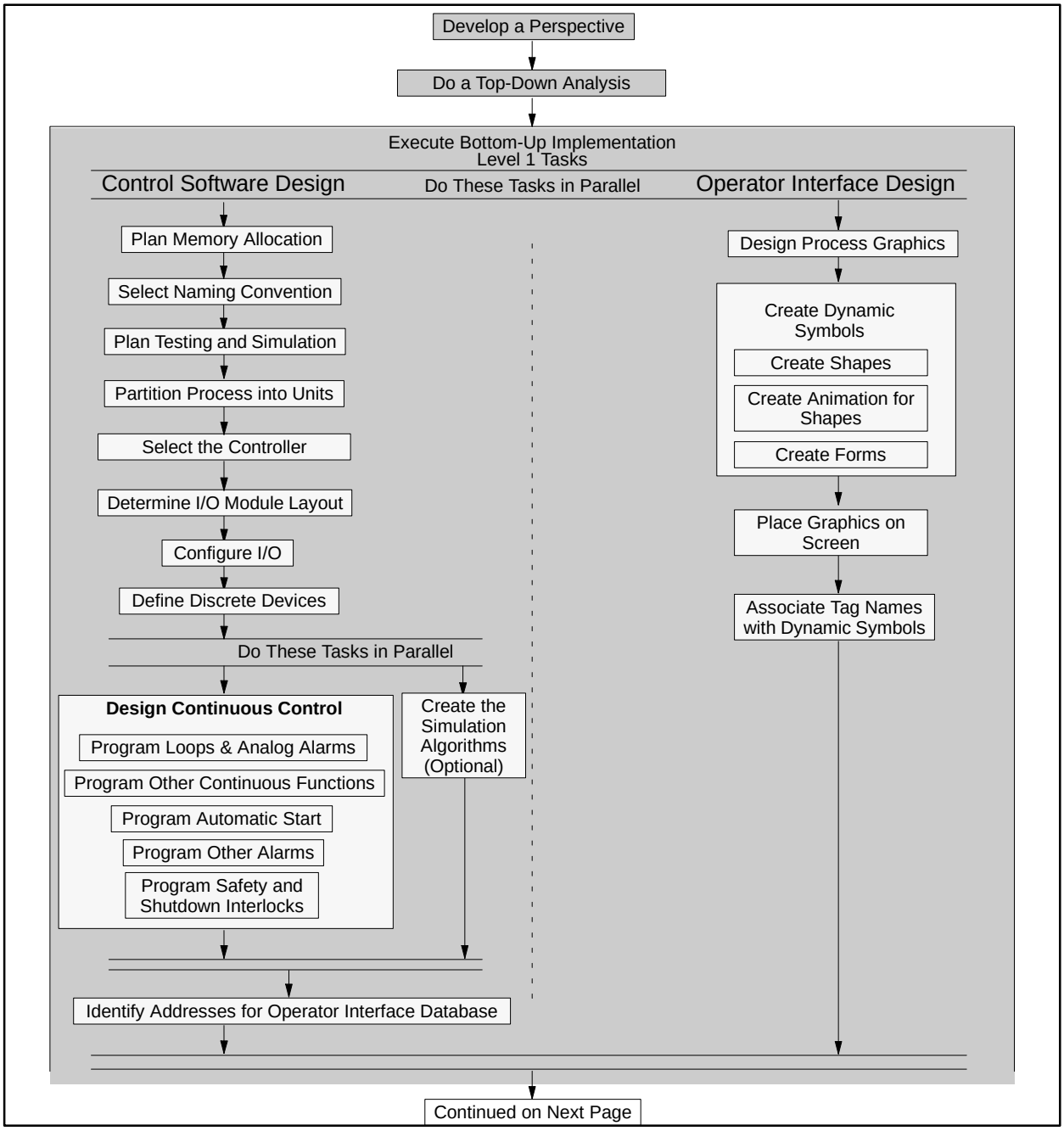


Figure 1-5 Steps of Designing Process Control

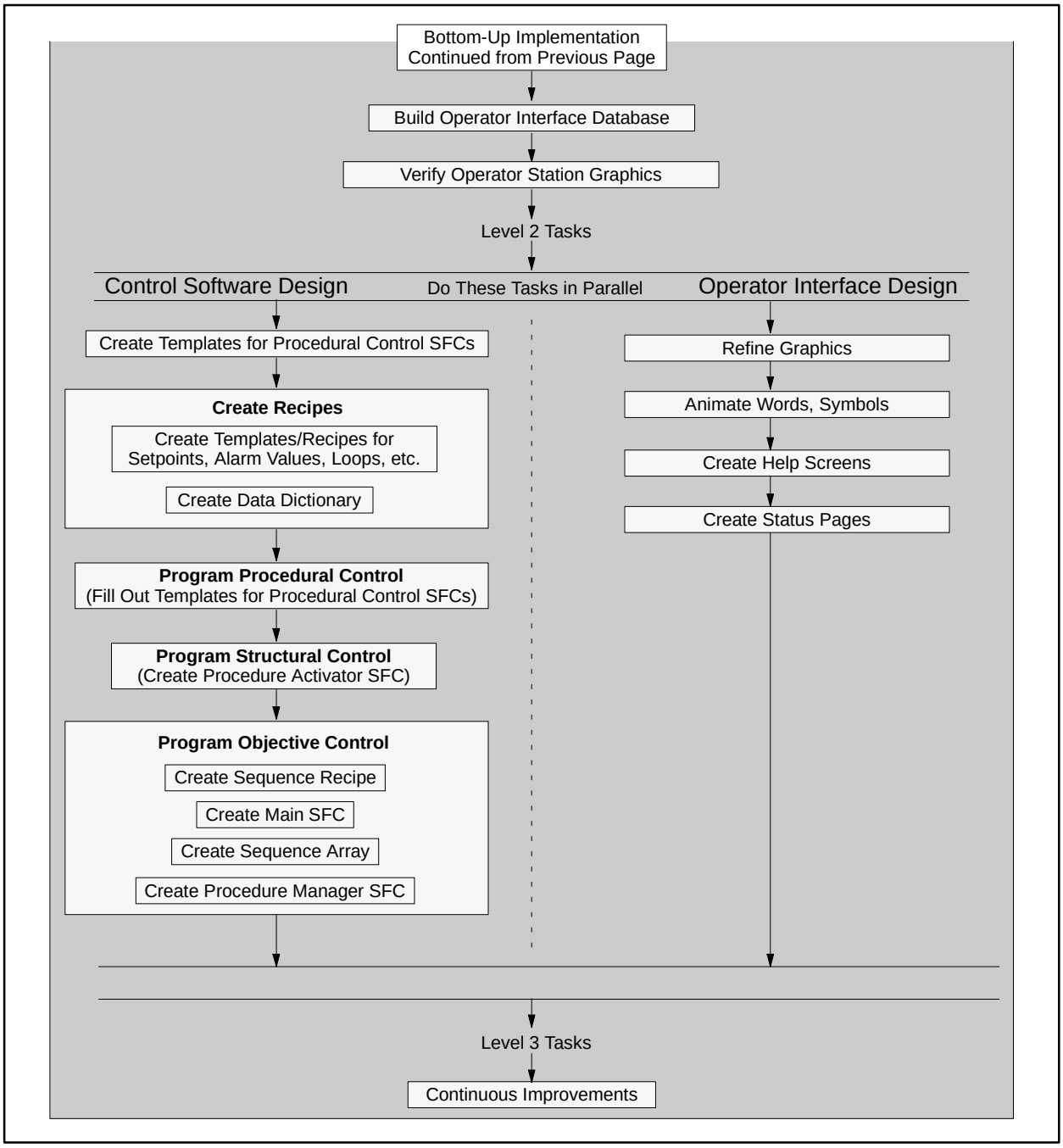


Figure 1-5 Steps of Designing Process Control (continued)

1.5 Create the Code — First Steps

In Section 1.4, you can find the list the tasks that comprise the bottom-up implementation. Figure 1-5 shows you the order for completing the tasks and also illustrates how the process design engineer can coordinate efforts with the operator interface design engineer. This section describes, in detail, what you need to do when you execute each task of the process control design.

Plan Memory Allocation

If you do not intend to monitor your process with an OSx operator interface, you must decide early in your process control design which controller memory locations are to be reserved for your operator interface. APT can be programmed to avoid these locations when you compile the program.

Select Naming Convention

Choose names for your I/O and devices that are meaningful so that you can easily identify their functions. If you intend to copy these objects for use elsewhere in the program, remember that names must be unique, as well as meaningful. Initially, try to choose names that are less than nine characters in length. Choose names that are easily transferred to the operator interface and avoid creating a cross-reference to which you must continually refer.

Plan Testing and Simulation

Begin planning your code tests early to anticipate problems that may occur. The simulation program is an optional task, but is recommended as an excellent way to test your code before process startup. The simulation allows you to concentrate on debugging the program without being concerned with the logistics of doing the tests. A software simulation program allows you to test your process control program by simulating real-time conditions. Since software routines can be stored as files, you can run them over and over very quickly and simply note the results.

APT includes a utility program called MAITT that simplifies the task of repeatable logic testing. You can design the test routines to generate reports that are stored or printed. With MAITT it is very easy to test the control system response to variable inputs. When you develop new code, you can easily test the existing code to verify that it still executes correctly.

Partition the Process into Units

Examine the partitions that you defined when you sub-divided the process during the top-down analysis. Each partition represents a portion of the functional organization of the physical plant. Dedicate one APT unit to each partition and begin adding the units to the APT hierarchy. Determine which units can be copied and used elsewhere in the program. Define only the original unit.

Select Controller

The controller that you use must be able to support the number of I/O points that you are planning for your process. Remember that the 560/560T and 565/565T/565P controllers support up to eight I/O channels and as many as 8192 I/O points. The 555 and the 575 support up to 8192 I/O points in one I/O channel. The 545 supports 2048 I/O points in one I/O channel, and the 545L supports 1024 I/O points in the local base. The S5 928B, 948, and 948R CPUs support 2048 inputs and outputs with process image, and 384 analog inputs and outputs through the periphery.

Determine I/O Module Layout

Determine the kinds and numbers of modules that you need. Plan their location carefully. Allow for expansion. If you try to reduce costs by using fewer modules and bases, you may ultimately increase the expense of expanding the system. When you use APT to develop the program, remember that for a Series 505 controller, the module table determines the address space, but the object belongs to the I/O Table. This allows you to test code even when the I/O configuration is not yet known. When you develop a program for an S5 controller, you determine the addresses by setting the dipswitches on the I/O modules. You then use the I/O Editor to enter these addresses into the I/O Table. For an S5 controller, you can test code without the I/O connected by selecting the image register in the I/O Table.

Configure I/O

Enter the I/O data into the I/O Symbolic Name Table: addresses, alarm limits, scaling data, offset information, etc. Take the time to document the I/O by including descriptive data and engineering units. This saves time and avoids confusion for other people who need to understand your system. When you make changes in the table, remember to validate the I/O after you exit the I/O Table.

Define Discrete Devices

Enter the device data into the Device Definition Table: type, commands, alarm times, limit switches, etc. Take the time to document the devices by including the descriptive data.

A Device Definition Table is available at both the Program Level and at the Unit Level. Devices defined at the Program Level can be referenced in any unit in that program. Devices defined at the Unit Level can be referenced only within that unit. When you make changes in the table, remember to validate the devices after you exit the Device Table.

Consider compiling the program and downloading it to the controller at this point. Do this to verify that devices are connected to the correct I/O points and that the alarm times are correct. However, before you can compile, remember that the field I/O associated with the APT device must be defined in the Module Definition Table and in the I/O Table for analog inputs.

1.6 Create the Code — Continuous Control Logic

At this stage of the process design, you begin writing the actual program code. Try to use continuous control logic to handle as many functions of your process as possible, and allow the sequential control code to do the scheduling for these functions. For this reason, it is best to begin work on the continuous control first.

As you design the continuous control code, determine the various control strategies and group them appropriately. The categories for the groups depend upon your own process and what is most convenient, not only for the current programmers, but also for those who must maintain and update the program. Use different Continuous Function Charts (CFCs) for the different functional control strategies, as shown in Table 1-1.

Table 1-1 CFCs Reflect Control Strategies

Function	CFC Name
Temperature Control	T_ctrl
Level Control	Lev_ctrl
Pressure Alarms	Prs_alrm
Agitator Startup	Agi_strt
Safety Interlocks	Interlck
Place Devices in Auto Mode	Auto_dev

Program the Simulation Math

You can program the math for the optional simulation as a continuously operating function. The simulation math is not necessarily the first code that you need to write, but you can develop it in parallel with the other continuous control logic. Place the simulation math in one or more math Continuous Function Blocks (CFBs), located in a CFC dedicated to program testing.

Program Loops, Analog Alarms, On/Off Control

Begin to write the code for those objects located under the APT Standard CFC icon. Think in terms of control strategies. Group the loops, for example, by logical function, and avoid being bound by artificial boundaries. Two cascaded loops, in which temperature control drives flow control, are best placed in their own unique group. Examine the CFC groupings in Figure 1-6 below.

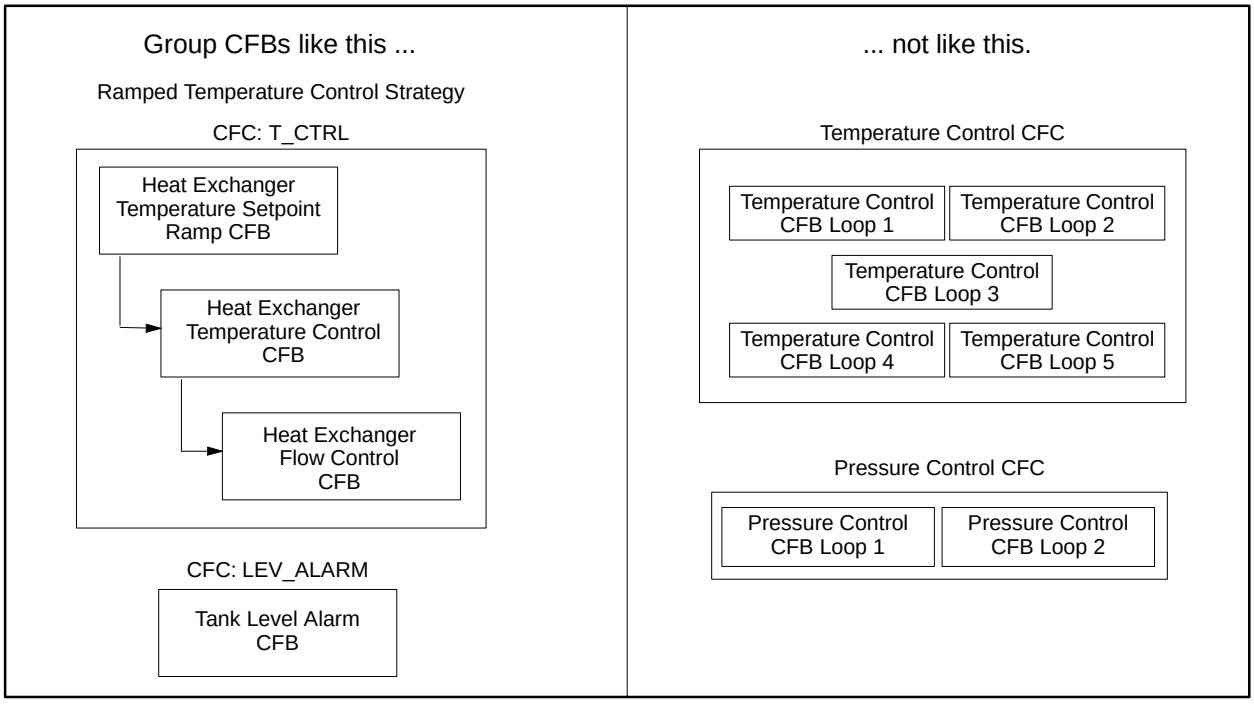

Group CFBs like this ...
Ramped Temperature Control Strategy
CFC: T_CTRL
Heat Exchanger Temperature Setpoint Ramp CFB
Heat Exchanger Temperature Control CFB
Heat Exchanger Flow Control CFB
CFC: LEV_ALARM
Tank Level Alarm CFB
... not like this.
Temperature Control CFC
Temperature Control CFB Loop 1
Temperature Control CFB Loop 2
Temperature Control CFB Loop 3
Temperature Control CFB Loop 4
Temperature Control CFB Loop 5
Pressure Control CFC
Pressure Control CFB Loop 1
Pressure Control CFB Loop 2

Figure 1-6 Example of CFC Groupings

For analog alarms, focus on programming the code that detects the alarm condition. Wait until you work on the interlock code, discussed on page 1-25 "Program Safety and Shutdown Interlocks," to program the code to correct the alarm condition.

Always validate, compile, and test code as you develop it. Do this in an incremental fashion to reduce the debug effort. Use a test controller that has no connected I/O.

Create the Code — Continuous Control Logic (continued)

Program Other Continuous Functions

Other forms of continuously operating functions include totalizers and code for a specific module, such as PEERLINK communications, Industrial Ethernet peer services, HSPI control logic, flashing lamps, etc. Focus on solving the problem, not on analyzing the flow of events, because the path can become very convoluted as you try to anticipate future events.

Remember to validate, compile, and test code as you develop it.

Program Automatic Start

The automatic startup for some devices, loops, and analog alarms is another function that is frequently better handled as a form of continuous, versus sequential, control.

When you define the conditions that control an operation, then you can create a continuous control strategy, based on those conditions, that handle the operation. Remember that the way you approach the problem determines how you find the solution. Think continuous control, not sequential control. Consider these typical process requirements for objects.

- The agitator starts whenever the water level is greater than 20% for more than a minute.
- The temperature controller is set to automatic whenever the flow controller is in the cascade mode.
- The supply solenoid opens whenever the flow controller is placed in automatic or cascade modes.
- The supply pump starts whenever the supply valve opens.

Remember to use the flag variables, which are objects that are similar to devices, but which have only two states: on or off. The flag variable provides a useful way to control objects through math statements. Objects respond to flags just as they would to commands.

Remember to validate, compile and test code as you develop it. Remember to do this in an incremental fashion to reduce the debug effort. Use a test controller that has no connected I/O.

Program Other Alarms

Other alarm conditions that you want to monitor may be too simple to be programmed as analog alarms, or the analog alarm function is not appropriate. These alarms typically have only one or two conditions that set off a signal to an interlock to handle the problem. Consider these examples.

- Monitor tank level — A declared boolean value is true when the level is greater than one value or less than another. When the level is outside the range, the boolean value becomes true and triggers interlocks.
- Monitor flow rate — A declared boolean value is true when the flow rate is less than a certain value for a specified period of time. When the flow rate is too low, a timer begins to time down. The boolean value becomes true and triggers interlocks when the timer times out. Note that the timer does not time down unless the flow rate is low.

Remember to validate, compile and test code as you develop it.

Program Safety and Shutdown Interlocks

The code that handles interlocks and other safety-related concerns is another example of logic that is best programmed in the form of continuous, rather than sequential, control.

As with loops and analog alarms, you need to group interlocks by logical function. It can be very difficult to determine the reason for the failure of a device, for example, when you must search through all the program interlocks for the one that has stopped operation of that device.

It is also best to place all the interlock code for an object in one location of the program. It is much less difficult to troubleshoot an interlocked object when the interlock code is not in several different places.

Dedicate one CFC in each unit to contain the interlock code for that unit. Consider dedicating one (interlock) CFB to handle interlock operations for each device and each CFB, as shown in Figure 1-7 below.

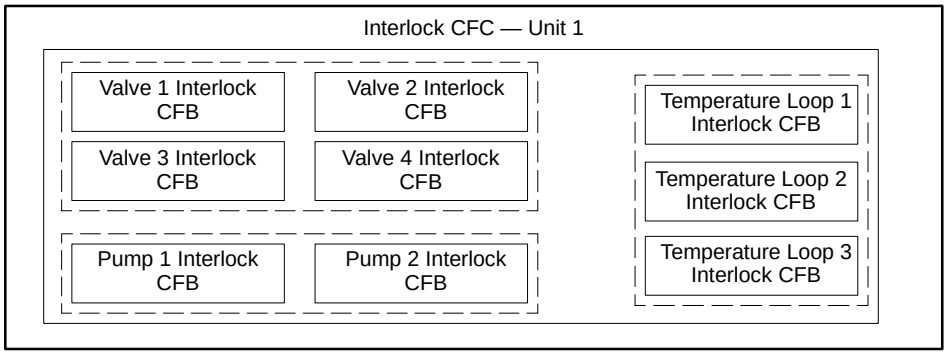

Interlock CFC — Unit 1
Valve 1 Interlock CFB
Valve 2 Interlock CFB
Valve 3 Interlock CFB
Valve 4 Interlock CFB
Pump 1 Interlock CFB
Pump 2 Interlock CFB
Temperature Loop 1 Interlock CFB
Temperature Loop 2 Interlock CFB
Temperature Loop 3 Interlock CFB

Figure 1-7 Example Interlock Blocks

Note that there is a practical limit to the number of interlock CFBs that you group within one CFC. If you have a large number of interlocks in a unit, consider placing all device interlocks of one device type into one CFB, all loop interlocks for one loop type into another CFB, etc., as shown in Figure 1-8.

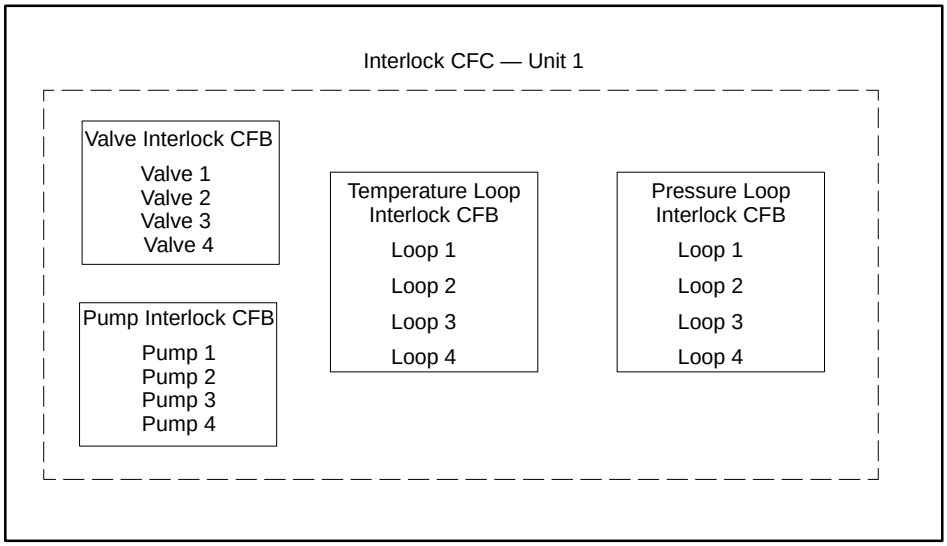


Figure 1-8 Example Interlock Groupings

Every APT device and CFB has a **.NRDY** extension. Use it in your interlock code as an indication of whether the device or CFB is ready for operation. Table 1-2 lists some interlock conditions and shows how the **.NRDY** extension can be used in the program code.

Table 1-2 Uses for the .NRDY Extension

Object to Go to Fail-Safe State	Condition	Code
Supply pump	The supply valve is not open.	SP.NRDY : = NOT(SV.OPND);

Flow controller in manual with zero output.	The temperature is too high.	FC.NRDY : = TC.INHHA;
		IF (EDGE (FC.NRDY)) THEN
		FC.OUT : = 0.0;
		ENDIF;

Remember to validate, compile, and test code as you develop it. Remember to do this in an incremental fashion to reduce the debug effort. Use a test controller that has no connected I/O.

1.7 Create the Code — Operator Interface Addresses/Graphics

Identify Addresses for Operator Interface Database

Follow the steps below to identify the APT objects that are to be referenced by the operator interface. This procedure was designed for an OSx system, but you can use it for any operator interface. Both steps can be done from the APT environment by selecting the appropriate options.

1. Mark tags for translation. In this step you select objects (tags) that are to be used by the operator interface and that must have unchanging controller addresses.

2. Compile the program with the **Yes** option selected in the Build Translate File field of the Compile Control File. If controller addresses are to remain fixed, select the **No** or **Append** option in subsequent compile operations.

This step builds the executable code used by the controller and creates a file that contains controller addresses that are fixed (unchanging) for each object that you marked in Step 1.

If your operator interface is an OSx system, you can use the file that was created in step 2 to build the OSx database. This is an automated process and is described on page 1-29, “Build Operator Interface Database.”

If your operator interface is not OSx, you can still mark objects and fix their addresses in the controller when you compile the APT program. The next step, building the operator interface database, is a manual procedure. You can use the file created in step 2 to identify the addresses that you must enter into the database.

If your operator interface is not OSx (or even if it is OSx), you do not have to mark tags for translation. You can reserve controller memory and assign selected addresses to the objects that you want to monitor with your operator interface. If you choose this method, you must include code in the controller program that moves the necessary data into the address that the operator interface monitors.

Build Operator Station Database

Enter the controller addresses for objects that are monitored by the operator interface into the operator interface database. Note that these addresses must remain unchanged in the controller program if the operator interface is to access data during run time. If you alter an address for an object, you need to make the appropriate change in the operator interface database.

You can use the APT Translate Tags utility to place the object's controller address into a database that is compatible with OSx. This is an automated procedure that also places other data into the database, including the object's name and description.

This is a manual procedure when your operator interface is not OSx. You must enter the object's controller address into the operator interface database. Consider writing a short program that can read the ASCII file generated by APT (**install.tag**) when you compile the program and then write the object's address to your operator interface database.

Verify Operator Station Graphics

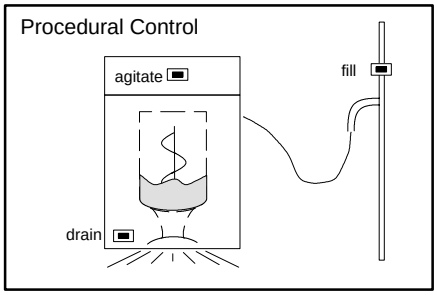
Download the program and connect the operator interface to the controller. Verify that the operator interface graphics are reflecting the operation of the controller program correctly. Do the icons change colors as they should? Are the correct messages being displayed? Can you use the operator interface to interact with the controller program, i.e., can you open a valve or turn on a motor?

You can use the APT Debug utility or MAITT, along with the operator interface, to do these tests.

Finish Level 1 Tasks

After you verify the operator station graphics, the Level 1 tasks are completed. Section 1.8 describes the Level 2 tasks.

1.8 Create the Code — Templates for Procedural Control



At this stage of the process design, you start on the Level 2 tasks. The continuous control logic is well defined. Program code may not be complete, but its development is under way. It is time to begin work on scheduling the continuously executing functions. This point in the process design marks the beginning of the work on the Sequential Function Chart (SFC) structures.

Begin by examining the continuous control strategies that you have already defined. Refer to your top-down analysis and determine what the procedures are. These procedures are handled by the individual SFCs used in a unit. Identify what the order of execution for these SFCs must be and how they interact with the continuously executing functions.

Subordinate SFCs

Give the SFCs meaningful names. Choose a naming convention that has meaning to your process and then use it consistently. In the laundry example, the subordinate procedures may have names such as Fill, Add_Soap, Agitate, and so on.

Think in terms of designing only SFC templates at this stage of the process design. You are laying only the foundation of a design structure. You will be coming back later in the design process to fill in the details. This means that you do not want to write complete and fully functional SFCs yet. Each SFC template must have a defined function, and each SFC must be activated by a temporary Main SFC, but it need not actually do any useful tasks yet. However, the program must be able to compile successfully. Figure 1-9 shows SFC templates for the laundry example.

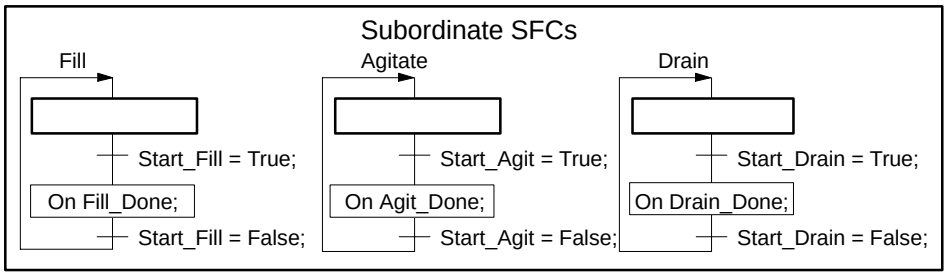


Figure 1-9 Example SFC Templates

The final transition of each subordinate SFC in the example waits for the start command to clear and ensures that the (temporary) Main SFC determines when the functions run. If the Main SFC waits until the done flag for an SFC is true and then clears the Start command, then each subordinate SFC executes only once and resets for another Start command.

Use declaration flags for start flags (Start_Fill, Start_Agit, Start_Drain) and for done flags (Fill_Done, Agit_Done, Drain_Done).

As you finish creating each SFC template, exit and validate the SFC. Then continue creating templates until all the initial operational procedures are defined.

Main SFC

When the individual SFC templates are identified, define an SFC to act as a procedure activator. This is the Main SFC, and its primary function is to activate the individual SFCs. The operation is comparable to a subroutine call in a BASIC program or a procedure in a C program. The subordinate SFCs, once activated, begin to monitor their respective Start commands and are executed as needed. The subordinate SFCs remain active: active/idle, active/working, or active/done and waiting.

Design this Main SFC with the knowledge that it may be the Main SFC only temporarily. As you refine the program and add enhancements, you may find the need to replace one Main SFC with another. The Main SFC in the laundry example is named **Phases** (Figure 1-10).

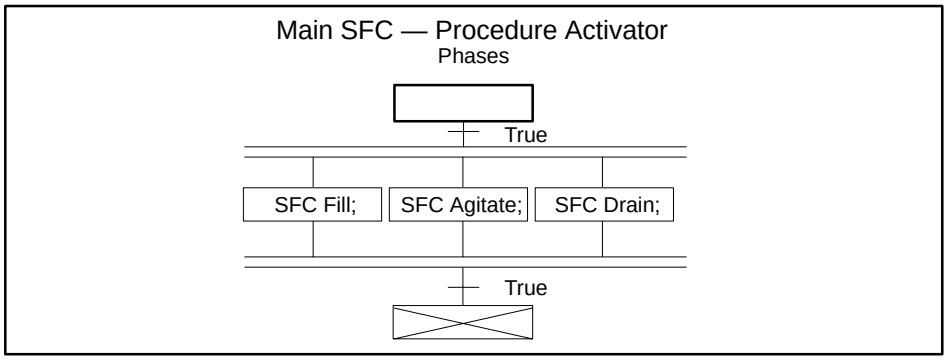


Figure 1-10 Example Procedure Activator SFC

The temporary Main SFC (the procedure activator) has an initial step followed by a true transition. Next is a parallel construction that contains a step for each subordinate SFC. Within each of these parallel steps a call to one of the subordinate SFCs is made. Note that none of the subordinate SFCs ever terminate; each is in an endless loop. Therefore, the procedure activator never reaches the exit step.

This approach allows you to test and adjust event scheduling without being distracted by the details of what the SFCs must do. The development of the actual SFC program code is discussed in Section 1.10.

1.9 Create the Code — Recipes and Recipe Templates

At this stage of the process design, the program structure is in place. It is time to return to the procedural control and complete this code. This point in the process design marks the beginning of the work on recipes and recipe templates.

APT recipes are multi-functional. Recipes are used to assign meaningful names to values, define operational setpoints, or to specify the order of operations. Treat the recipe as a tool that can help provide meaning and structure to a program.

Recipes are associated with a template that defines the element name, data type, description, and engineering units for the element. You define the template at the program content level of the hierarchy. You define values for the individual recipe elements through the Recipe Usage Table editor.

Build the Template

To create a recipe, begin by defining a template. Try to think of all the possible setpoints that you may need and include them in your list. Figure 1-11 shows the setpoints for the laundry example and their corresponding entries in a template.

Operational Setpoints → Enter setpoints into the template. → Recipe Template

	Element	Type	Description	Eng. Units
Temperature setpoint #1 Hot/Warm/Cold	Tmp_sp1	I	Temp. SP #1	Celsius
Temperature setpoint #2 Hot/Warm/Cold	Tmp_sp2	I	Temp. SP #2	Celsius
Temperature setpoint #3 Hot/Warm/Cold	Tmp_sp3	I	Temp. SP #3	Celsius
Fill level #1 High/Medium/Low	Fill_lev1	I	Fill level #1	Gallons
Fill level #2 High/Medium/Low	Fill_lev2	I	Fill level #2	Gallons
Fill level #3 High/Medium/Low	Fill_lev3	I	Fill level #3	Gallons
Wash agitate time #1 Average/Extra long	Wsh_agi_tim1	I	Wash agitate time #1	Minutes
Wash agitate time #2 Average/Extra long	Wsh_agi_tim2	I	Wash agitate time #2	Minutes
Rinse agitate time #1 Average/Extra long	Rns_agi_tim1	I	Rinse agitate time #1	Minutes
Rinse agitate time #2 Average/Extra long	Rns_agi_tim2	I	Rinse agitate time #2	Minutes

Figure 1-11 Example Recipe Template

Build the Recipe

Create a recipe within the main unit of the process, the unit that handles the primary task(s) of the process. This will be the working recipe, the recipe that contains the current recipe element values when the process is active. When you download a recipe during runtime, you will be copying one of your library recipes into this working recipe.

Assign the working recipe a short name, e.g., WR (for Working Recipe) so that the element names can be as long as possible. Then enter the value for each element.

Figure 1-12 shows the setpoint values for the laundry example. The values, Hot, Warm, Medium, etc., are integer constants that you need to define in the Declaration Table. This can be done either before or after you enter them as values in the recipe value fields. Define each one at either the global or the unit level, and assign it a unique numerical value.

NOTE: APT only accepts text in recipe value fields if the text is the name of either an integer or a real that is declared as a constant.

Recipe Values

Value	Units	Element Name	Description	Type
Hot	Celsius	Tmp_sp1	Temp. SP #1	I
Warm	Celsius	Tmp_sp2	Temp. SP #2	I
Cold	Celsius	Tmp_sp3	Temp. SP #3	I
High	Gallons	Fill_lev1	Fill level #1	I
Medium	Gallons	Fill_lev2	Fill level #2	I
Low	Gallons	Fill_lev3	Fill level #3	I
Average	Minutes	Wsh_agi_tim1	Wash agitate time #1	I
Ex_long	Minutes	Wsh_agi_tim2	Wash agitate time #2	I
Average	Minutes	Rns_agi_tim1	Rinse agitate time #1	I
Ex_long	Minutes	Rns_agi_tim2	Rinse agitate time #2	I

Figure 1-12 Example Recipe

Choose values for names as is appropriate for your program, but always assign the following values to these loop modes, so that they correspond to the loop extension .SMODE. (For information about .SMODE, see the section on PID (Chapter 2) in the *SIMATIC APT Programming Reference (Graphics/Math) Manual*.)

- In_Automatic — 4
- In_Cascade — 6
- In_Manual — 2

Create Data Dictionary

Build the Dictionary Template Create a data dictionary as a structured means of defining meaningful names for use in the program. The recipe and template are preferable to multiple declaration tables for holding data dictionary values. Using the recipe and template keeps all the information in one place, makes it easy to reference, and helps to avoid duplicate entries that can make troubleshooting difficult. See Figure 1-13.

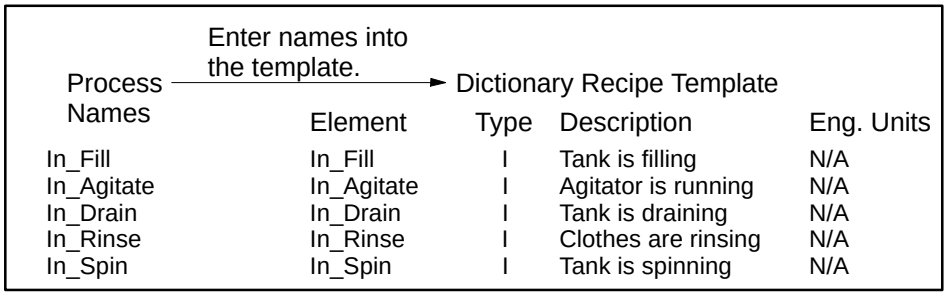


Figure 1-13 Example Data Dictionary Template

Build the Dictionary Recipe Create a program-level recipe named D. Keep the name short so that anyone who examines the program will focus on the meaning of the extension and not the recipe name, e.g., **D.IN_FILL**, **D.IN_SPIN**. See Figure 1-14.

Recipe

Value	Units	Element Name	Description	Type
8	N/A	In_Fill	Tank is filling	I
16	N/A	In_Agitate	Agitator is running	I
24	N/A	In_Drain	Tank is draining	I
32	N/A	In_Rinse	Clothes are rinsing	I
40	N/A	In_Spin	Tank is spinning	I

Figure 1-14 Example Data Dictionary Recipe

Keep values unique to avoid confusion. Use multiples of eight if you intend to use OSx to animate tags that use values that are defined in the data dictionary.

NOTE: You can designate that your data dictionary be only a data structure on the recipe usage table form. A data structure does not get the handshaking code that recipes get, but can be marked for tag translation.

1.10 Create the Code — Procedural Control Logic

Continue your work on sequential control by writing the code to handle specific procedures. Select one of the SFC templates that you developed for procedural control and the begin to enter the code that executes the appropriate tasks. Do this for all the SFC templates. Your priority is to make sure that each SFC does the intended task, and does it correctly. Be sure to test your code thoroughly.

In the laundry example, consider an SFC called **Fill**, which helps coordinate the fill task for the washing machine. The steps and transitions are shown in Figure 1-15 and described below.

- Step S1 waits for a signal from the procedure activator (called **Phases** in the laundry example) that the fill procedure is to begin.
- Transition T1 [**Strt_fill**] becomes true when the start command Strt_fill is true. An SFC at a higher management level, which you program for Objective Control (page 1-40), latches on the start command.
- Step S2 [**Increment fill_s; Fill_level : = wr.fill_sp; Temp_setpt : = wr.tempt_setpt;**] loads setpoints for level and temperature based on values in the working recipe. S2 also increments a counter to keep track of the number of times that the **Fill** SFC is executed. Transition T2 is always true.
- Step S3 contains no code and waits for the level to reach the selected level. Water level is controlled in part by a CFB that opens the hot and cold water valves when a new setpoint is loaded. An interlock CFB is programmed to shut off the valves by setting the **cold_water.NRDY** and **hot_water.NRDY** bits when the level reaches the setpoint.
- Transition T3 [**Fill_at_sp**] becomes true when the level reaches the level specified by the setpoint.
- Step S4 [**On fill_done; Clear stop_fill**] turns on a flag to indicate that the fill task is finished and clears the stop command.
- Transition T4 [**Not (strt_fill)**] waits for the start command **Strt_fill** to clear. This path loops back and program flow waits for **Strt_fill** to become true again.

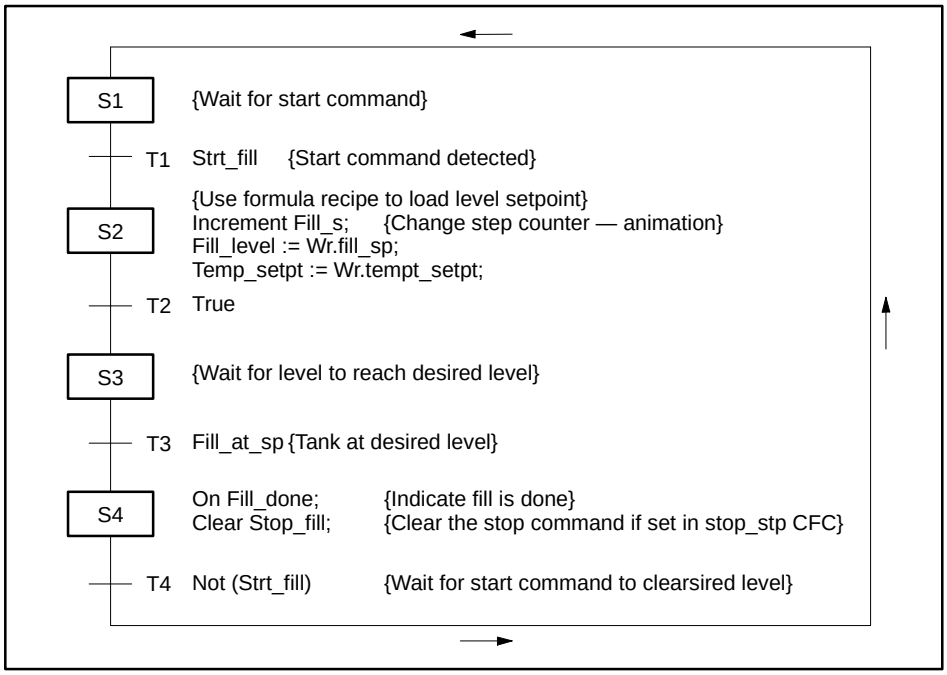


Figure 1-15 Example Procedure SFC

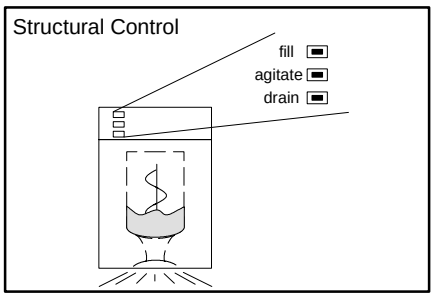
This example reinforces important concepts about the design of process control.

- Use continuous control functions to do the actual work in the process.
- Allow the sequential control functions to do the scheduling tasks.

In the laundry example, the control of the valves is handled by CFBs, while the factors that involve scheduling and setpoints are handled by the SFCs.

As you finish the code for each procedural SFC, exit and validate the SFC. Correct any errors and then compile the program and test it with the APT Debug Utility. See Chapter 3 for suggestions about using Debug.

1.11 Create the Code — Structural Control Logic



You completed most of the work that comprises the design of structural control when you created the templates and procedure activator for procedural control (Section 1.8). To finish the design of the structural control, you need to finish the code for the procedure activator SFC and verify these items.

- The procedure activator SFC can successfully call each procedural SFC.
- Each procedural SFC operates correctly when called by the activator.

In the laundry example, the temporary Main SFC called **Phases** coordinates the activation of the procedural SFCs. The steps and transitions are shown in Figure 1-16. The actual operation of **Phases** is very simple. Once called by an SFC at a higher management level, which you program for Objective Control (page 1-40), **Phases** activates all the procedural SFCs in parallel.

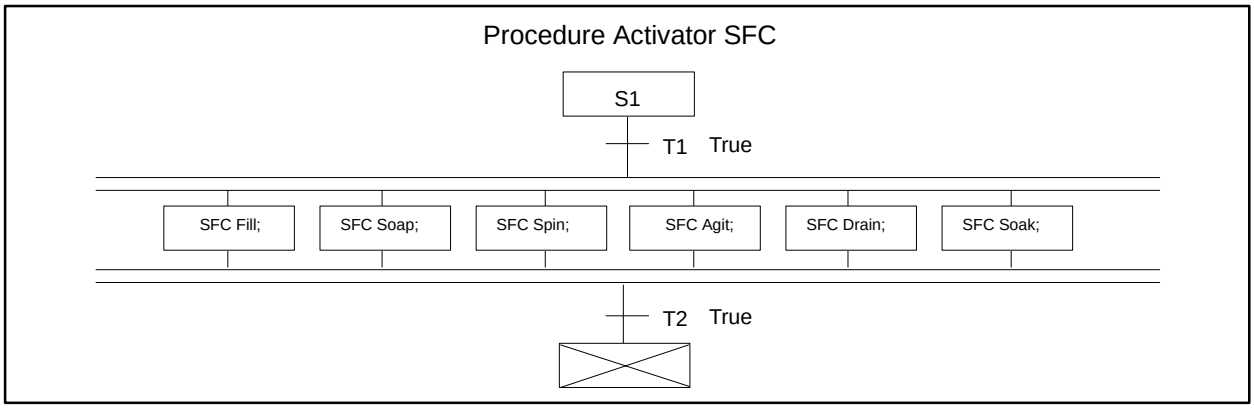


Figure 1-16 Example Procedure Activator SFC

The relationship between the procedure activator SFC and the procedural SFCs is shown in Figure 1-17.

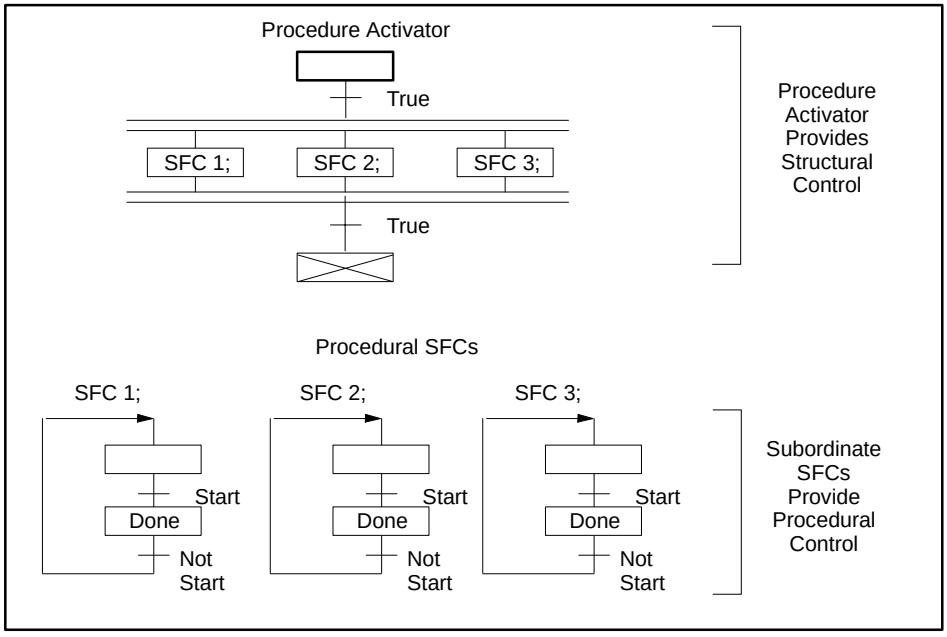
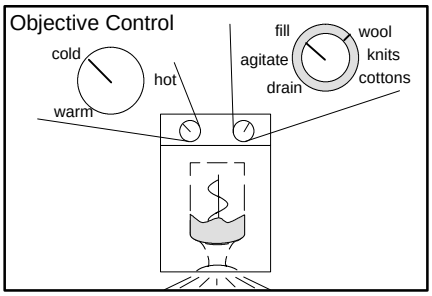


Figure 1-17 Relationship of the Procedure Activator to Procedural SFCs

When you finish the code for the procedure activator SFC, exit and validate the SFC. Correct any errors and then compile the program and test it with the APT Debug Utility.

1.12 Create the Code — Objective Control Logic



Finish the Level 2 control by writing the code for objective control. In this you are imposing upon the structural control a flexible execution pattern. The execution pattern is defined by a data set that is loaded from a sequence recipe. The sequence recipe controls the start commands for the operational SFCs and defines when to test their done flags.

Implementation of objective control comprises four tasks.

- Build a sequence recipe and template.
- Create the permanent Main SFC.
- Create a sequence array to hold the values contained in the sequence recipe.
- Create the procedure manager SFC.

Build the Sequence Recipe Template

The sequence recipe defines the execution order of the various operational SFCs. The recipe may call for the multiple execution by certain SFCs and not call some SFCs at all. Note that if multiple executions are needed, then you need to have this contingency in mind when you design the operational SFCs.

Start by determining what all the various steps of the execution pattern are. List these in simple meaningful terms, but enter more generic terms into the element field of the template. Figure 1-18 shows the steps that are appropriate for the laundry example and their corresponding entries in a template called Sequence.

Process Steps → Enter steps into the template. → Recipe Template

	Element	Type	Description	Eng. Units
Set to wash cycle	Step_1	I	Step 1	N/A
Fill the tank	Step_2	I	Step 2	N/A
Add the soap	Step_3	I	Step 3	N/A
Wait for the soap to be added	Step_4	I	Step 4	N/A
Wait for the fill to complete	Step_5	I	Step 5	N/A
Start the agitator	Step_6	I	Step 6	N/A
Wait for the agitation to complete	Step_7	I	Step 7	N/A
Start the drain	Step_8	I	Step 8	N/A
Wait for the drain to complete	Step_9	I	Step 9	N/A
⋮	⋮	⋮	⋮	⋮

Figure 1-18 Example Sequence Recipe Template

Define the Sequence Recipe Value Names

Before creating the sequence recipe, choose carefully the names that you use for the recipe values. There is an implied action associated with every name. For example, the word *initialize* means: latch the start command for the associated operational SFC to true. The word *wait_init* means: monitor a "done flag" until the message is true; and then reset the start command to false. For the laundry example, the word *R_fill* means: latch the *strt_fill* command.

Build the Sequence Recipe

Create a recipe within the main unit of the process. This will be the Sequence Working Recipe, the recipe that contains the current recipe element values when the process is active. Assign the working recipe a short name, e.g., SWR (for Sequence Working Recipe) and associate it with the template Sequence.

Figure 1-19 shows the step action values for the laundry example. Remember that the recipe values must be declared integer constants because APT only accepts text in recipe value fields when the text is the name of an integer constant.

Recipe Values

Value	Units	Element Name	Description	Type
Set_wash		Step_1	First step	I
R_fill		Step_2	Second step	I
R_soap		Step_3	Third step	I
Wait_soap		Step_4	Fourth step	I
Wait_fill		Step_5	Fifth step	I
R_agit		Step_6	Sixth step	I
Wait_agit		Step_7	Seventh step	I
R_drain		Step_8	Eighth step	I
Wait_drain		Step_9	Ninth step	I
⋮		⋮	⋮	⋮

Figure 1-19 Example Sequence Recipe

Create the Permanent Main SFC

At this point, it is time to create the SFC that will be the Main SFC for the unit. The Main SFC controls the startup of the Procedure Activator SFC (**Phases**) and another SFC (to be created later as a part of Objective Control) that will act as a scheduler for the operational SFCs. Another SFC that the Main SFC can control, and which can be added later, coordinates the loading of product recipes.

In the laundry program, an example of the Main SFC is shown in Figure 1-20. The steps and transitions are described below.

- Step S1 [**Op_mode : = d.in_auto;**] sets the operation mode to automatic. Transition T1 is always true because there is no need to wait.
- Step S2 contains no code but is required because the parallel construction does not allow a loop to return directly below the top crossbar. Transition T2 is always true because there is no need to wait.
- Step S3 [**SFC Phases;**] calls the procedure activator SFC **Phases**. Transition T6 is always false so that this path never terminates.
- Step S4 [**Op_strt : = true;**] sets the boolean entity Op_strt to true. Op_strt is used to inform the operator that the process is ready to start. The operator's acknowledgement sets Op_strt to false, which allows program flow to advance past transition T3.
- Step S5 [**SFC Download;**] calls the SFC **Download**, which downloads recipe information to the working recipe. Transition T4 is always true because program flow does not advance until the exit step of **Download** is active.
- Step S6 [**SFC Batch;**] calls the SFC **Batch**, which acts as a scheduler for the operational SFCs. Transition T5 is always true. This path loops back and program flow waits for an acknowledgement from the operator to continue.

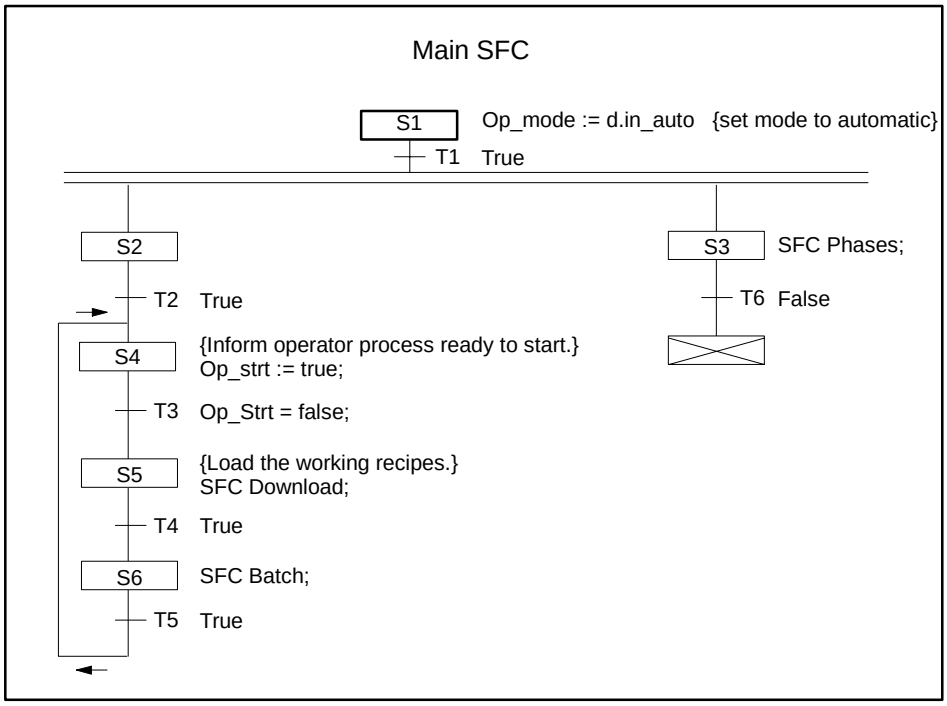


Figure 1-20 Example Main SFC

Create the Sequence Array

The sequence array is essentially a sequential data table. A table pointer (with a **.PTR** extension) can be advanced to read the next data point or reset to move to the beginning of the data table. The table **.IOUT** extension is loaded with the current data point after an advance command. The table **.EMPTY** extension is true when the pointer reaches the end of the table.

The sequence array has these functions.

- Hold the values of the working sequence recipe SWR.
- Determine when to set the start command for operational SFCs.
- Determine when to wait for done responses from the operational SFCs.

Set the size of the sequence array to the same number of elements in the sequence recipe.

Create the Procedure Manager SFC

The procedure manager operates as a graphical while loop, which is initiated by the operator, and provides these services.

- Advance the pointer through the sequence array, move data into the sequence array from the sequence recipe, and reset the pointer.
- Turn on/off the start commands to the operational SFCs.
- Provide for bad data in the recipe.

In the laundry example, the SFC called **Batch** acts as the procedure manager. The steps and transitions are shown in Figure 1-21 and are described below.

- Step S1 [**Reset seq_selector;**] resets the sequence selector. The sequence selector pointer contains zero and **Select.IOUT** will be unaffected by the reset. Transition T1 is always true because there is no need to wait.
- Step S2 [**SFC mode_ctrl;**] calls the SFC that controls the mode and the sequence advance.
- Transition T2 [**Seq_selector.IOUT = set_wash**] is true when the current recipe points to the wash operation. Step S3 [**Wash_op : = wash;**] loads wash_op with the wash variable. Transition T3 is always true.
- Transition T4 [**(Seq_selector.IOUT = end_wash) OR seq_selector empty**] detects the end of the batch. Step S4 [**Enable dat_reset**] enables a CFB that clears all the batch data before allowing another batch to run.
- Transition T5 [**Seq_selector.IOUT = set_rinse**] is true when the current recipe points to the rinse operation. Step S5 [**Wash_op : = rinse;**] loads wash_op with the rinse variable. Transition T6 is always true.
- Transition T7 [**Seq_selector.IOUT = r_fill**] is true when the current recipe points to the **Fill** SFC. Step S6 [**Latch strt_fill;**] sets the request to fill flag to true. Transition T8 is always true.
- Transition T9 [**(Seq_selector.IOUT = wait_fill) AND strt_fill**] is true when the tank has started to fill and the process is waiting for the fill task to finish. The recipe must set **strt_fill** to true before the wait is accepted. At Step S7 the process waits for the **Fill** SFC to finish.
- Transition T10 [**Fill_done**] is true when the **Fill** SFC has finished. Step S8 [**Clear strt_fill;**] clears the start fill flag. Transition T11 is always true.

- Step S9 contains no code but is required because a convergence must be followed by a step. Transition T12 is always true.
  Transitions T13–T37 and Steps S10–S24 handle scheduling for the **Soap**, **Soak**, **Agitate**, **Spin**, and **Drain** SFCs with code similar to that used for the **Fill** SFC.

- The branch containing transitions T38 and T39 (always true) and Step 25 (no code) allows the SFC to continue running if no other transitions evaluate to true in the event of bad recipe data.

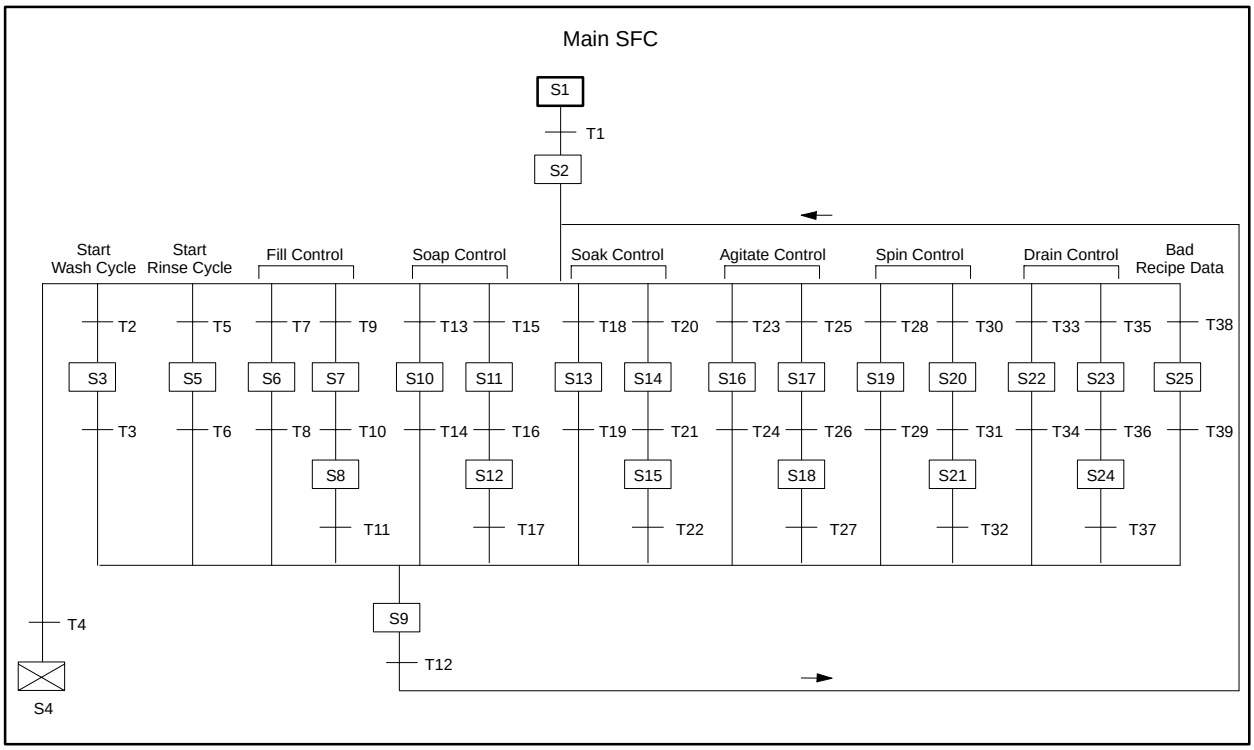


Figure 1-21 Example Procedure Manager SFC

The procedure manager SFC activates operations sequentially or in parallel. The sequence recipe specifies whether an operation must finish before the next operation is started or whether several operations are started simultaneously.

NOTE: Although operations execute in parallel, they are activated sequentially due to the nature of the graphical execution pattern. If execution interlocking and synchronization is required, include code for this within the various independent operational SFCs.

Figure 1-22 shows how the levels of control (procedural, structural, and objective) are implemented by the SFCs used in the laundry example.

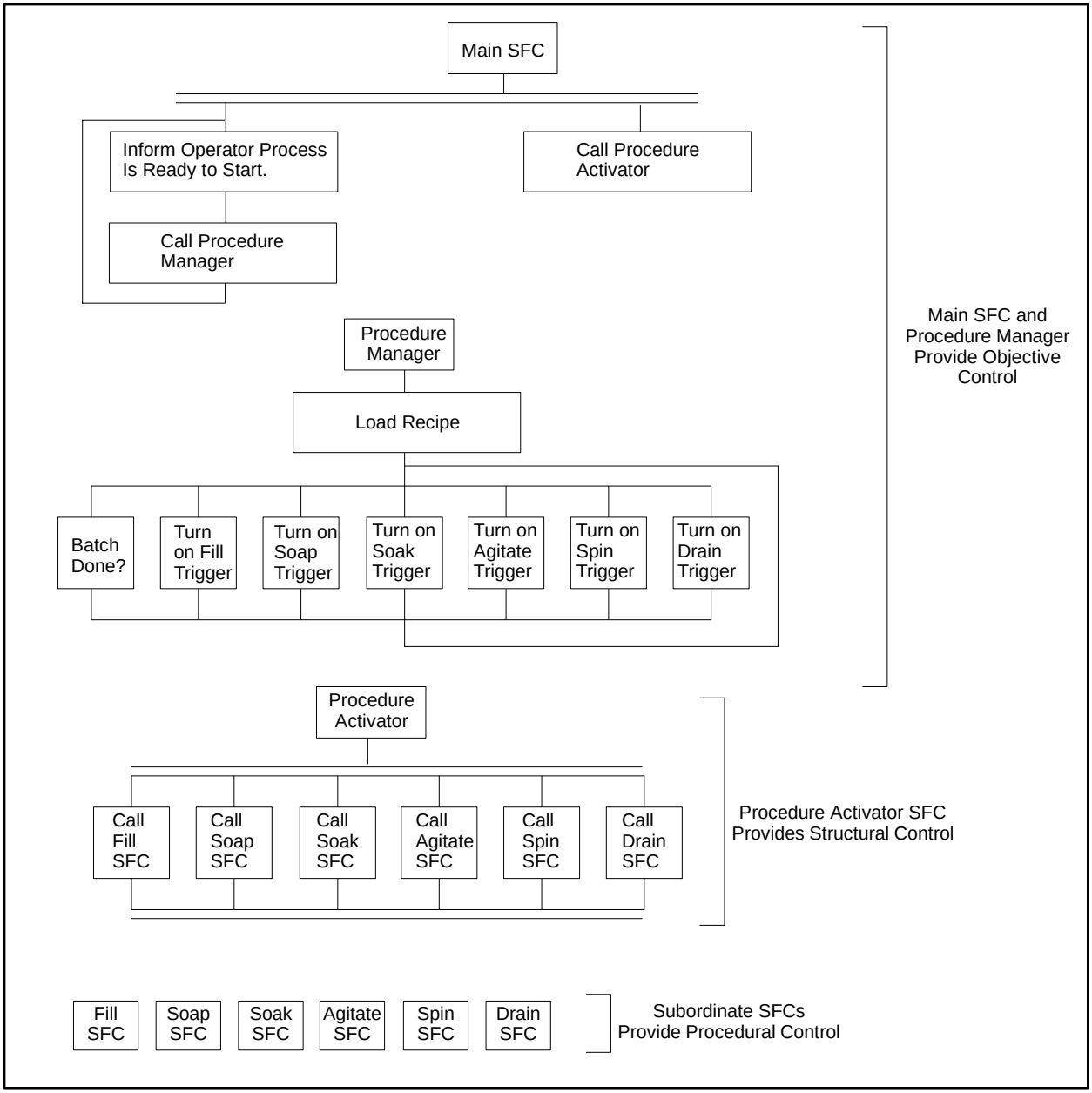


Figure 1-22 Sequential Control Hierarchical Relationship

Figure 1-23 shows how the levels of control (procedural, structural, and objective) are reflected by the APT hierarchy.

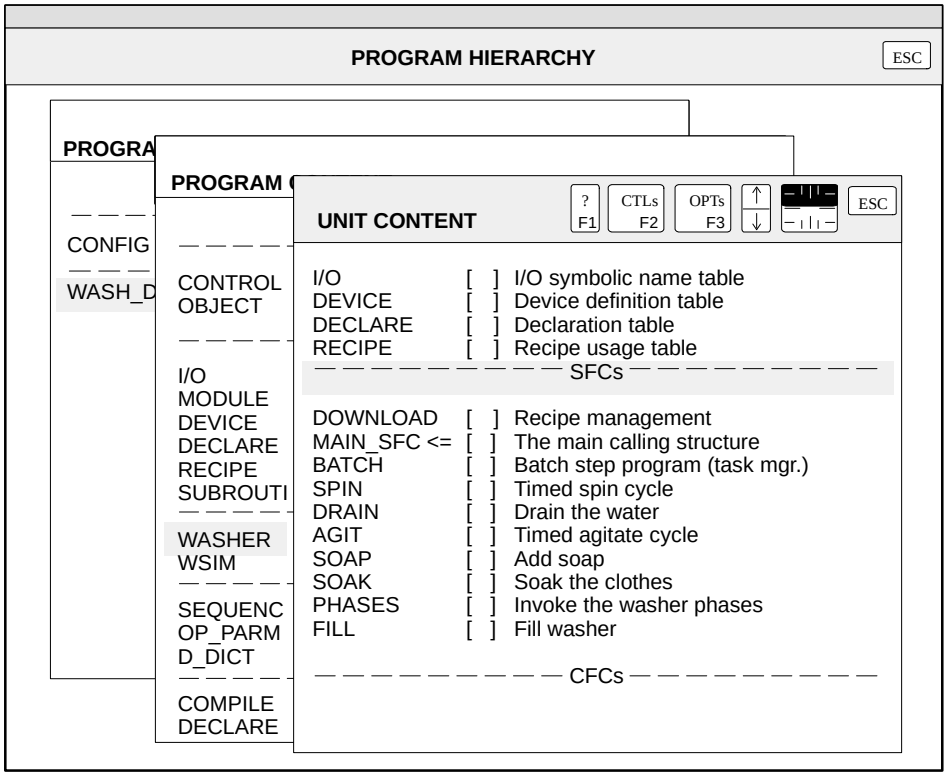
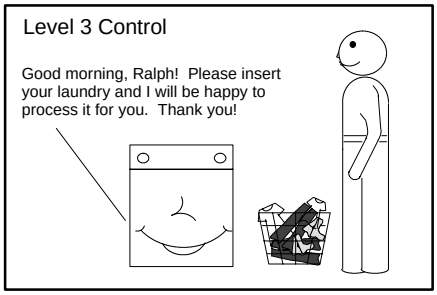


Figure 1-23 APT Hierarchical Relationship

Finish Level 2 Tasks

After you create the logic for objective control, the Level 2 tasks are completed. Turn to Section 1.13 for a description of the Level 3 tasks.

1.13 Create the Code — Level 3 Control



At this stage of the process design, you start on the Level 3 tasks. Although you can follow the same general approach to designing controls for most types of processes, each process is unique. Consider the next step to be a series of steps—an ongoing set of improvements to your program. Add as many as you need to make your program more efficient or easier to use. You can stop enhancing the program at any time; or, you can continue indefinitely. See Figure 1-24.

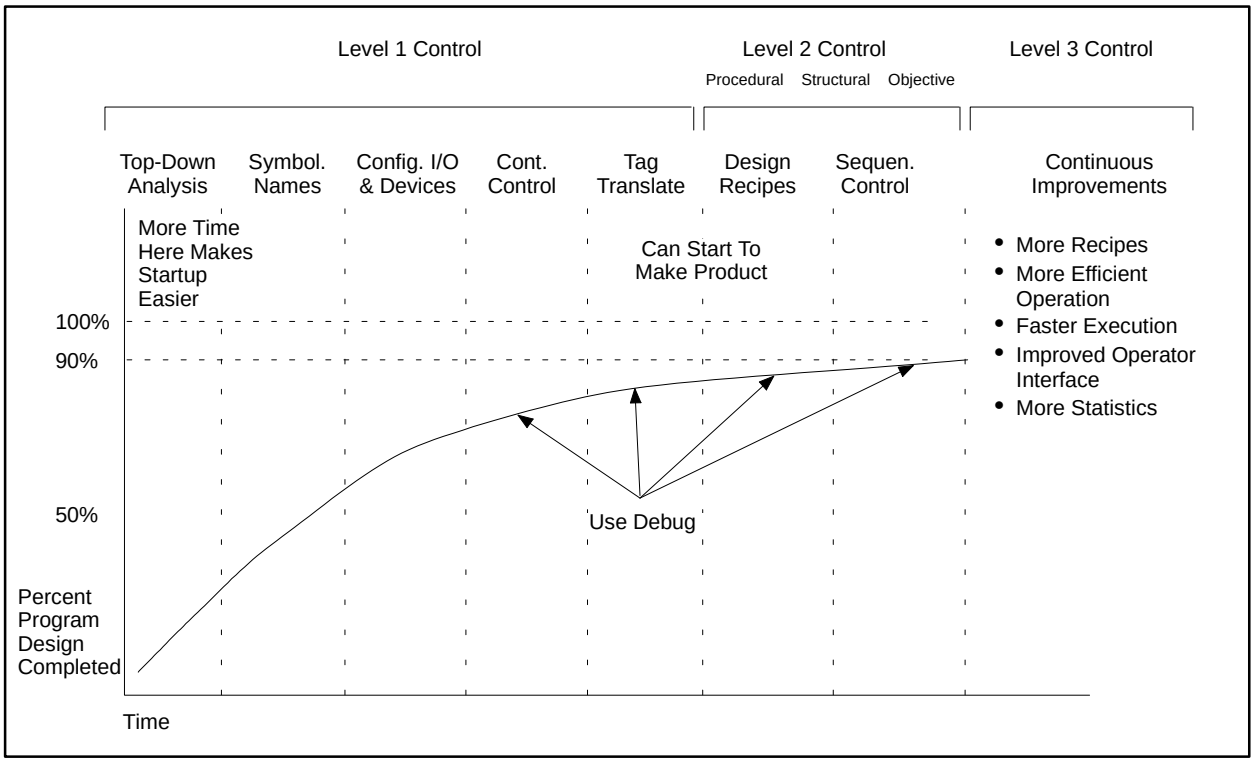


Figure 1-24 Project Development/Time Relationship

Add Normal SFCs

As your process evolves, you may want to add steps to the sequence control. These steps may not have been important enough to hold up process startup, but to improve production you want to add them now. For example, your quality control may determine that tank cleanings are necessary to increase output. For this you need to write new SFCs and incorporate them into the current program.

Add Safe-State SFCs

You may discover better ways to handle exception conditions that occur in your plant. You can add safe-state SFCs that provide a smoother transition to a holding condition or that waste less product. You may decide that it is preferable to salvage your product or recycle it, for example, instead of dumping the product when an emergency such as a power failure occurs.

Send Additional Data to the Operator Interface

You may be interested in pointing out additional data to the operator during runtime operation. For an OSx system, you can consider writing code that reads SFC status attributes, such as SPIN, FILL, AGITATE, etc., for each SFC. Then when the attribute is true, you can have an icon that is specific to the unit or device change color to reflect the status change.

Allow Operator to Cancel Operations

You may want to write code that enables the operator to advance the process to the next step before the current procedural SFC has finished. Although the solution to this requirement may appear to be complex, it is easily coded—if you have designed the SFCs with care.

When your program design is modular and well-structured, the key to the solution rests in the fact that most procedures spend a lot of time waiting for the termination condition to become true.

You can design a CFB to stop steps by programming it to monitor a stop command and to turn on a stop command when the operator requests that the step be terminated. You can add the terminate flag to the appropriate transitions within an SFC, and to the device interlocks for those devices that are manipulated by the SFC.

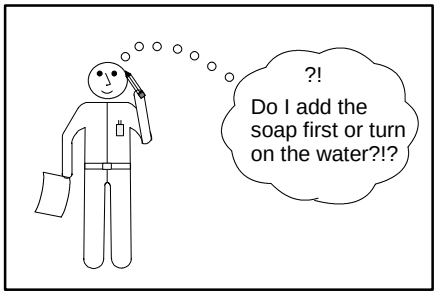
In the laundry example, the **Fill** SFC spends nearly all its time waiting for the tank to fill with water. To enable an operator to terminate this SFC, declare the integer **kill_step** and provide the code that loads it with the name of the step to be terminated. The following math in a CFB causes the **Fill** SFC to transition to its last step and clears the terminate flag.

```
If ((kill_step = fill_tmp) and start_fill then
        Latch kill_fill:        {activate the kill fill step}
        Kill_step : = 0;        {reset the kill command}
Endif;
```

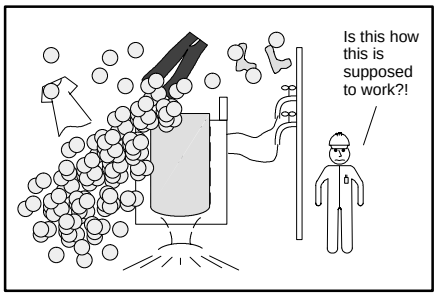
You should also use the **kill_fill** flag in the appropriate interlock blocks to ensure that all devices that need to return to the de-energized state respond to the **kill_fill** flag.

1.14 When You Create Code

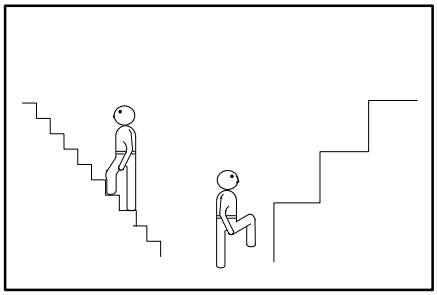
Suggestions Consider these software design guidelines when you begin writing the program.



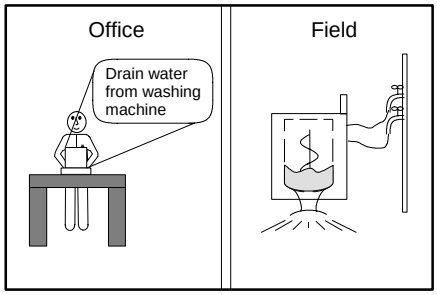
Understand the problem. Do not write any code for a section of a program until you are certain that you know how this section is supposed to function and can explain it clearly to a colleague. Otherwise, you can do a considerable amount of rewriting. Your program may become patched and inefficient.



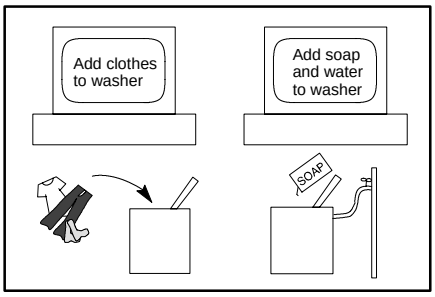
Verify code manually. Do not base your understanding of the operation of a program section solely on your belief in your code generation capabilities and the descriptions of the functions in the controller user manuals. Prove to yourself that the code does the task that you intend. Manipulate the I/O and/or the control words to see if the devices respond appropriately.



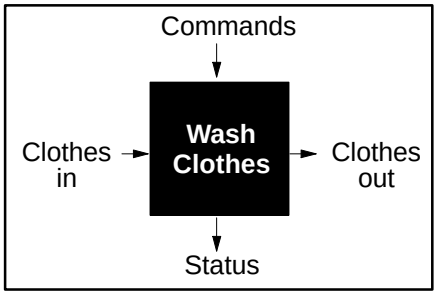
Take small steps. Write your program in small sections and then test each section. When you successfully test a section of the program, do not create several sections of code assuming that they will test successfully. Subsequent testing can be difficult and time-consuming.



Verify communications path. Use the operator station to control the field equipment as soon as possible during the process control design. It is best to identify communications problems between the operator station, controller, and field devices early.

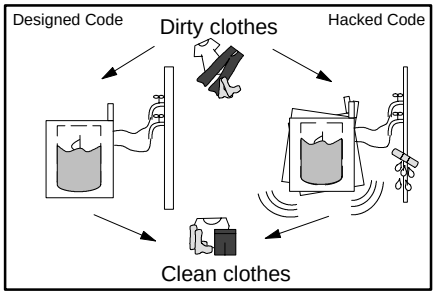


Program structure reflects process. The application program is a window into the process and the program's structure should be similar to the process. Be sure to make the appropriate functional partitions in the process. When you write code, the program will be structurally sound and more efficient. It will be easier to write since you will have small, well-defined functions to program.



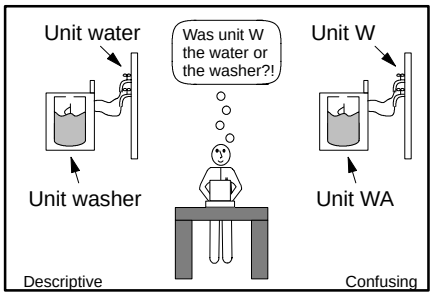
Use black box design. Almost any task can be viewed as a black box with a set of inputs and a set of outputs. After you have analyzed the task and defined the external view, then you can change the task any number of times without affecting other tasks that use it. The external view changes only when the functional requirements of the task change. When the external view changes then other tasks must be changed as well. This approach is a very powerful and useful design approach.

When You Create Code (continued)

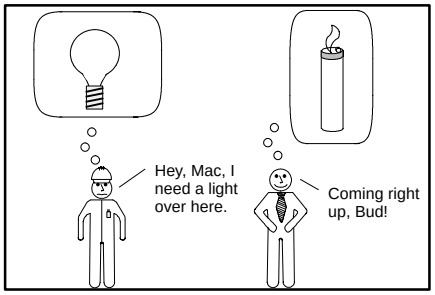


Designed vs. "hacked" code. Recognize the difference between implementing a design and "hacking" code. A designed system is highly structured and modular. Designed code is well thought out and tasks are designed as black boxes. Hacked code is typically disorganized, is written quickly, and with little planning.

The code designer thinks through the requirements and charts a course to meet the requirements in an efficient and understandable way. The code designer maintains the overall perspective and structure while laying out the detailed tasks. When problems occur, the code designer redesigns a program so as to maintain cohesiveness and structure. A hacker writes and rewrites code until it works.



Select names carefully. Use descriptive, meaningful names to identify items in the program. This will avoid confusion, makes it easier to maintain a program and to transfer it to the next programmer.



Verify Requirements. Communicate often with the other people who are involved in the system development. This helps ensure that you fully understood the operations people, for example, when they gave you their list of needs.

1.15 What Can APT Do for Me?

There are many reasons for creating your application program with APT. Choose APT for your programming tool if any of these reasons apply to you.

- You prefer to use a structured top-down approach to design your program.
- You do not like to be concerned with the details of RLL or Special Function programming (Series 505) or STL (S5).
- You prefer to use meaningful names in your program, such as Tank_1_Drain instead of V213.
- You intend to monitor your process with OSx.
- You like to select and use pre-designed and tested solutions within your program instead of designing your own.
- You find it easier to use a pre-designed, menu-driven debug utility to test your program.
- Your application is flexible and needs to be recipe-controlled.
- Your application is relatively large and detailed. The more complicated a program is, the easier it is to use APT to create it.
- You need a means of coding both continuous and sequential control within the program. APT provides a regulatory control language (CFC) and a language (SFC) for scheduling and coordinating control of the application.
- You need to document your program. APT makes it easy to provide comments and descriptions to reference when it is time to update the program.

Chapter 2

Program Descriptions

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2.1 Examining the Washer Example

Loading the Washer Example for Series 505 Controllers

To install *WASH_DEM*, follow these steps.

1. Insert the APT software CD in your CD-ROM drive; or, if you created diskettes from the CD, insert DISK8 in your diskette drive.

2. Ensure that the current DOS "path" environment includes the path to the APT executables directory. For example, if APT is installed at D:\APT, enter the following command:

   ```
   PATH
   ```

   If D:\APT is not included in the list output by `PATH`, add it by entering the following command:

   ```
   PATH=%PATH%;D:\APT
   ```

3. If you are loading *WASH_DEM* from the CD, enter the following command, substituting your diskette drive for E, and your disk drive containing the APT database for D:

   ```
   E:\DISK8\LOADDEMO  E:\DISK8\WASH_DEM  D:
   ```

   If you are loading *WASH_DEM* from diskette, enter the following command, substituting your diskette drive for A, and your disk drive containing the APT database for D:

   ```
   A:\LOADDEMO  A:\WASH_DEM  D:
   ```

NOTE: You must have at least 539K free conventional memory to load this demo program.

The APT database is typically on the drive where you installed the APT software, unless you selected the **Configure Directories** option during installation or reconfigured your system at a later time.

If you have configured APT so that the APT software is installed on multiple drives and/or in non-standard directories, then you must ensure that the environment variables APT_DB and APT_COMMON exist and are assigned appropriate values. See page 1-17 for more information.

If these environment variables are properly set and you are loading from CD drive G, enter the following command:

```
G:\DISK8\LOADDEMO  G:\DISK8\WASH_DEM
```

If you are loading from diskette drive B, enter the following command:

```
B:\LOADDEMO  B:\WASH_DEM
```

NOTE: The *WASH_DEM* example program accesses direct memory addresses to simulate an actual process. For this reason, warnings are generated the first time that you compile the program. On subsequent compiles, no warnings occur if you do not choose a forced compile.

Examining the Washer Example (continued)

Process Description for the Washer

The process consists of a tub with level and temperature sensors and has the following components.

- Hot and cold water valves
- Soap dispenser
- Agitator motor
- Spin motor with an analog speed sensor
- Open door sensor
- Vibration monitor.

Process Functions of the Washer

The process is to be used to wash and rinse clothes and provides these services.

- The system provides the capability of washing large, medium, and small loads of clothes. The fill-level setpoint is user selectable.
- The temperature of the wash and rinse cycles is user selectable. The temperature of the wash cycle can be hot, warm, or cold. The temperature of the rinse cycle can be warm or cold.
- The process provides two wash cycles, normal or permanent press. The process sequence is identical for the two cycles, but the setpoints, such as agitation time, are different.
- The operator has the capability of placing the process on hold and of advancing the process to the next step in the cycle at any time.

  The operator has the capability of aborting the process at any time. The abort sequence empties the tank and spins the contents of the tank before resetting the system.

  The operator has the capability of monitoring the state of the wash sequence and of modifying the steps in the sequence while the process is executing.
- Programmed interlocks prevent the spin motor from running when the door is open or when the vibration sensor is tripped. Alarms notify the operator when either of these two conditions are true. The operator is required to acknowledge the vibration alarm before the system can restart.

P&ID for the Washer

Figure 2-1 shows the P&ID for the Washer Example program.

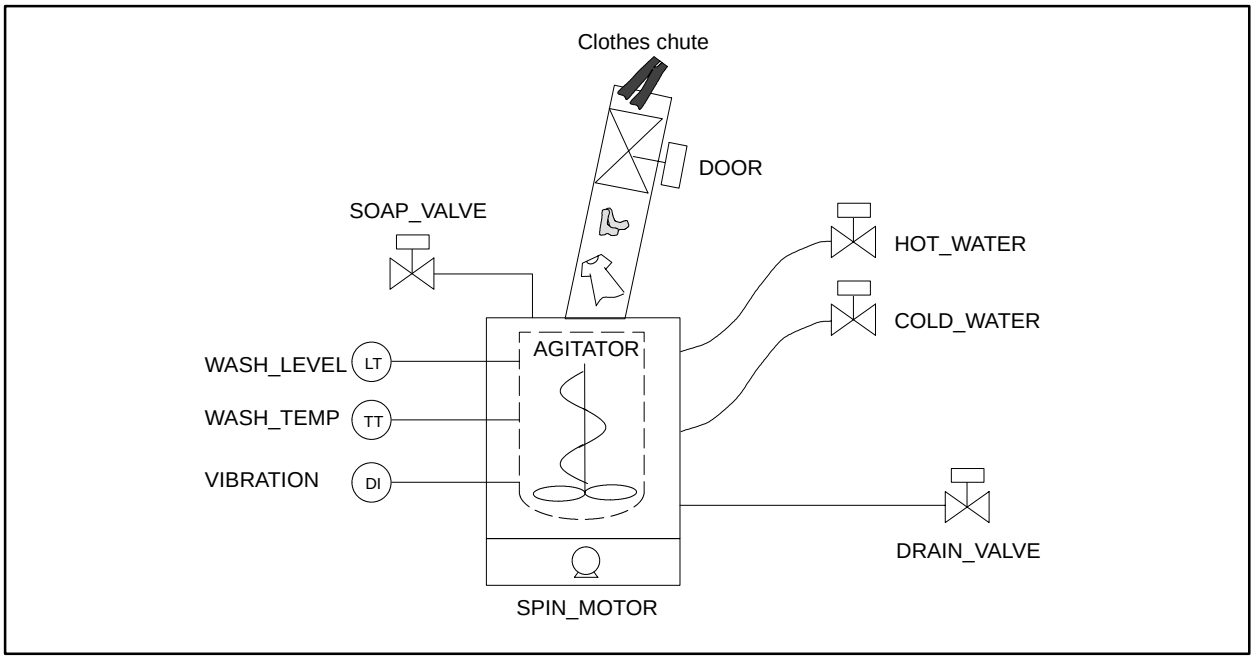

Figure 2-1 Washer Example P&ID

Process I/O for the Washer

Table 2-1 lists the Series 505 I/O for the Washer Example program.

Table 2-1 Washer Example I/O

Name	Type	Address	Subtype	Units	Low Range	High Range	Description
Spin_speed	AI	WX0059	T	%	0.0	100	Spin motor speed
Wash_level	AI	WX0057	T	%	0.0	100	Washer level
Wash_temp	AI	WX0058	T	degf	0.0	150	Wash temperature
Agit_rv	DI	X0045					Agitator run verify
Cw_vlv_ols	DI	X0043					Cold water valve ols
Door_open	DI	X0047					Washer door is open
Dvlv_ols	DI	X0041					Drain valve open switch
Hw_vlv_ols	DI	X0042					Hot water valve ols
Soap_ols	DI	X0046					Add soap limit switch
Spin_rv	DI	X0044					Spin motor run verify
Vibration	DI	X0048					Vibration sensor
Agit_cmmd	DO	Y0053					Agitator start
Cw_cmmd	DO	Y0051					Cold water valve
Dvlv_cmmd	DO	Y0049					Drain valve open/close
Hw_cmmd	DO	Y0050					Hot water open command
Soap_cmmd	DO	Y0054					Add soap valve open

2.2 Examining the Cooker Example

Loading the Cooker Example for Series 505 Controllers

To install *FOOD545N*, follow these steps.

1. Insert the APT software CD in your CD-ROM drive; or, if you created diskettes from the CD, insert DISK8 in your diskette drive.

2. Ensure that the current DOS "path" environment includes the path to the APT executables directory. For example, if APT is installed at D:\APT, enter the following command:

   ```
   PATH
   ```

   If D:\APT is not included in the list output by `PATH`, add it by entering the following command:

   ```
   PATH=%PATH%;D:\APT
   ```

3. If you are loading *FOOD545N* from the CD, enter the following command, substituting your diskette drive for E, and your disk drive containing the APT database for D:

   ```
   E:\DISK8\LOADDEMO  E:\DISK8\FOOD545N  D:
   ```

   If you are loading *FOOD545N* from diskette, enter the following command, substituting your diskette drive for A, and your disk drive containing the APT database for D:

   ```
   A:\LOADDEMO  A:\FOOD545N  D:
   ```

The APT database is typically on the drive where you installed the APT software, unless you selected the **Configure Directories** option during installation or reconfigured your system at a later time.

If you have configured APT so that the APT software is installed on multiple drives and/or in non-standard directories, then you must ensure that the environment variables APT_DB and APT_COMMON exist and are assigned appropriate values. See page 1-17 for more information.

If these environment variables are properly set and you are loading from CD drive G, enter the following command:

```
G:\DISK8\LOADDEMO  G:\DISK8\FOOD545N
```

If you are loading from diskette drive B, enter the following command:

```
B:\LOADDEMO  B:\FOOD545N
```

NOTE: The *FOOD545N* example program accesses direct memory addresses to simulate an actual process. For this reason, warnings are generated the first time that you compile the program. On subsequent compiles, no warnings occur if you do not choose a forced compile.

Process Description for the Cooker

The process consists of two cookers and a weigh tank. The weigh tank is connected physically to the two cookers by means of a transportation network that consists of a blower fan and a screw auger. Material moves along the auger until it either drops into an open diverter valve into a cooker, or it passes beyond the boundary of the cooker network and falls into the waste bin.

The operator always has the option of placing the system into one of three execution modes.

Automatic — The selected recipe automatically executes until finished.

Jog — At the end of each operation the operator is prompted for permission before the recipe proceeds. This is a semi-automatic mode.

Manual — The operator selects which operation to execute and provides a parameter(s) for the operation.

The operator can switch between any of the three modes at any time, although the request may be ignored until a logical time in the recipe execution.

The system allows the operator to repeat the previous recipe step, skip to the next recipe step, or to restart the recipe at a particular step.

Any step can be cancelled during execution. During a batch run, the effect of cancelling a step is to advance the recipe to the next logical step.

Process Functions of the Cooker

The process makes product according to a product recipe that specifies the sequence of operations, the quantities of materials, and the processing time for a particular product. The following operations are provided for all products.

- The operator initiates the process by selecting one of three strategies.

  A) Download a recipe from the operator console. The recipe specifies the number of batches.

  B) A recipe stored in the controller is used as the active recipe. The recipe contains the number of runs for a batch. The operator can modify the number of runs before executing the recipe.

  C) The operator selects a campaign: a series of runs that uses a collection of recipes stored internally. The operator selects the recipes, their order of execution, and the number of times that they are executed.

- When a run begins, the weigh tank weighs an amount of material and then transfers the material to one of the cookers.

- While the weigh tank weighs material, water is added to the cooker.

- The cooker heats up to a temperature, which must be stable for two minutes.

- The cooker ramps the temperature to the cook setpoint.
- The product cooks (soaks) while maintaining the temperature.
- Water is added to the cooker to begin the cool-down step.
- At the end of the cool-down step (three minutes) the operator is notified that the product is ready for transfer.
- The operator initiates the procedure of pumping out the cooker.
- If a change in product is made, or if no more runs are specified, the cooker is cleaned. Water is added to the cooker, which is then heated.
- The tank agitator starts automatically whenever the tank level is greater than 20% of its maximum value. The agitator shuts off if a low level occurs for more than one minute. The pump-out pump stops on a low-level time out. Programmed interlocks protect all tanks from overheating and overfilling.

P&ID for the Cooker

Figure 2-2 shows the P&ID for the Cooker Example program.

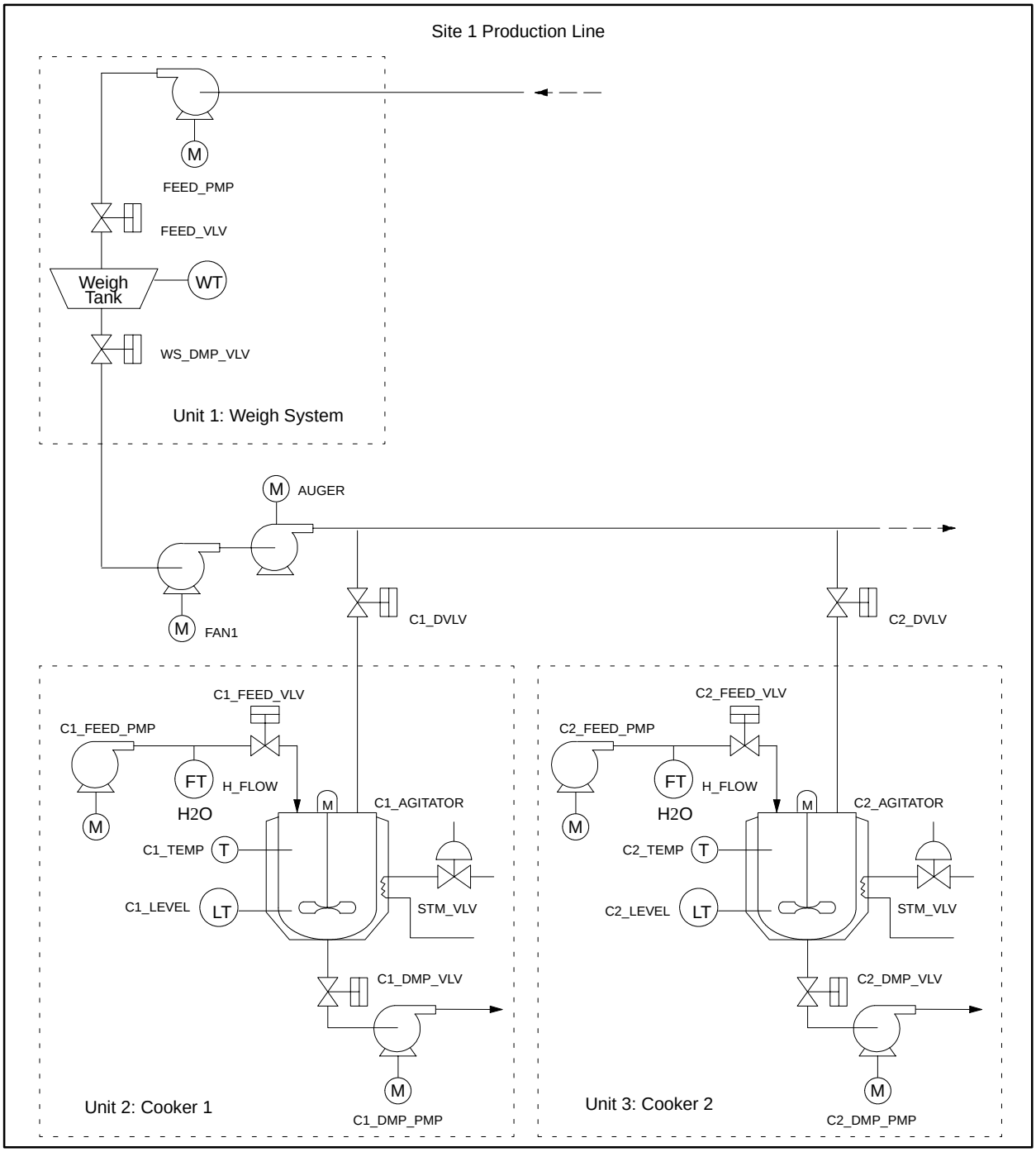

Figure 2-2 Cooker Example P&ID

Process I/O for the Cooker

Table 2-2 lists the Series 505 I/O for the Cooker Example program.

Table 2-2 Cooker Example I/O

Cooker Number One							
Name	**Type**	**Address**	**Subtype**	**Units**	**Low Range**	**High Range**	**Description**
C1_dvlv_cmd	DO	Y0009					Cook. 1 diverter cmd I/O
C1_dvlv_ols	DI	X145					Cook. 1 diverter valve ols
C1_dmp_vlv_r	DO	Y0153					Reverse direction: dump vlv
C1_dmp_vlv_f	DO	Y0154					Forward direction: dump vlv
C1_dmp_vlv_c	DI	Y0082					Kettle system dump vlv cls
C1_dmp_vlv_o	DI	Y0083					Kettle system dump vlv ols
Agitator_cmd	DO	Y0155					Agitator start cmd I/O
Agitator_stp	DO	Y0157					Agitator stop cmd I/O
Agitator_rv	DO	Y0086					Agitator run verify
C1_dmp_pmp_c	DO	Y0158					Dump pmp strt/stop cmd. I/O
C1_dmp_pmp_r	DI	Y0081					Kettle system dump vlv rI/O
Feed_io_hi	DO	Y0159					H2O feed batch vlv opn hi I/O
Feed_vlv_cmd	DO	Y0161					H2O feed vlv energiz opn I/O
Feed_vlv_ols	DI	Y0085					H2O feed vlv ols
Feed_pmp_cmd	DO	Y0160					H2O feed pmp cmd I/O
Feed_pmp_rv	DI	Y0084					H2O kettle sys dump vlv rI/O
Flash_lamp	DO	Y0162					Lamp I/O: flashing oper. act.
C1_drn_flow	R	V-Memory					Flow from the kettle
C1_level	AI	WX0018	Z	percent	0	100	Level in percent
C1_temp	TC	WX0177	J	F	-346	1400	Cooker temperature
H2O_flow	AI	WX0019	Z	ft3	0.0	1.0	Water flowing into tank
Load_cell_wt	AI	WX0017	Z	lbm	0.0	3000.0	Load cell reading lbm
Stm_valve	AO	WY0169	Z	ft3			Steam valve
Weigh Tank							
Name	**Type**	**Address**	**Subtype**	**Units**	**Range**	**Range**	**Description**
Auger_cmd_io	DO	Y0113					Auger start relay
Auger_run_v	DI	X0097					Auger run verify contact
Fan1_cmd_io	DO	Y0114					Fan 1 start relay
Fan1_run_ver	DI	X0098					Fan 1 run verify contact
Feed_pmp_cmd	DO	Y0116					Feed pump cmd I/O
Feed_pmp_rv	DI	X0099					Feed pump run verify
Feed_vlv_cmd	DO	Y0115					Feed valve cmd I/O
Feed_vlv_ols	DI	X0100					Feed vlv OLS
Load_cell_wt	AI	WX0129	Z	lbm	0.0	3000.0	Load cell reading lbm

2.3 Examining the Heat Exchanger Example

Loading the Heat Exchanger Example for Series 505 Controllers

To install *HX_DEMO*, follow these steps.

1. Insert the APT software CD in your CD-ROM drive; or, if you created diskettes from the CD, insert DISK8 in your diskette drive.

2. Ensure that the current DOS "path" environment includes the path to the APT executables directory. For example, if APT is installed at D:\APT, enter the following command:

   ```
   PATH
   ```

   If D:\APT is not included in the list output by `PATH`, add it by entering the following command:

   ```
   PATH=%PATH%;D:\APT
   ```

3. If you are loading *HX_DEMO* from the CD, enter the following command, substituting your diskette drive for E, and your disk drive containing the APT database for D:

   ```
   E:\DISK8\LOADDEMO  E:\DISK8\HX_DEMO  D:
   ```

   If you are loading *HX_DEMO* from diskette, enter the following command, substituting your diskette drive for A, and your disk drive containing the APT database for D:

   ```
   A:\LOADDEMO  A:\HX_DEMO  D:
   ```

The APT database is typically on the drive where you installed the APT software, unless you selected the **Configure Directories** option during installation or reconfigured your system at a later time.

If you have configured APT so that the APT software is installed on multiple drives and/or in non-standard directories, then you must ensure that the environment variables APT_DB and APT_COMMON exist and are assigned appropriate values. See page 1-17 for more information.

If these environment variables are properly set and you are loading from CD drive G, enter the following command:

```
G:\DISK8\LOADDEMO  G:\DISK8\HX_DEMO
```

If you are loading from diskette drive B, enter the following command:

```
B:\LOADDEMO  B:\HX_DEMO
```

NOTE: The *HX_DEMO* example program accesses direct memory addresses to simulate an actual process. For this reason, warnings are generated the first time that you compile the program. On subsequent compiles, no warnings occur if you do not choose a forced compile.

Process Description for the Heat Exchanger

The process consists of a heat exchanger with flow and temperature analog sensors. The system is made up of these components.

- On/off water valve
- Regulatory control valve
- Pump

Process Functions of the Heat Exchanger

The process is flexible and recipe controlled. The temperature control strategy is based on a cascade control scheme with a temperature controller and a flow controller. The temperature controller must transition to automatic whenever the flow controller is placed into the remote or cascade mode of operation. The process provides these services:

- A startup phase heats the process to an initial temperature.
- A shutdown phase shuts off the system and ensures that the process has cooled down.
- A ramp setpoint phase controls temperature ramping from an initial starting point to an endpoint at a controlled rate.
- The process includes a soak procedure that is a timed wait.
- The process includes a profile procedure that uses a time/temperature profile to specify the process temperature curve.

The order of execution for the phases of the process is flexible and changeable. The product recipe determines which phases operate and when they are active.

P&ID for the Heat Exchanger

Figure 2-3 shows the P&ID for the Heat Exchanger program.

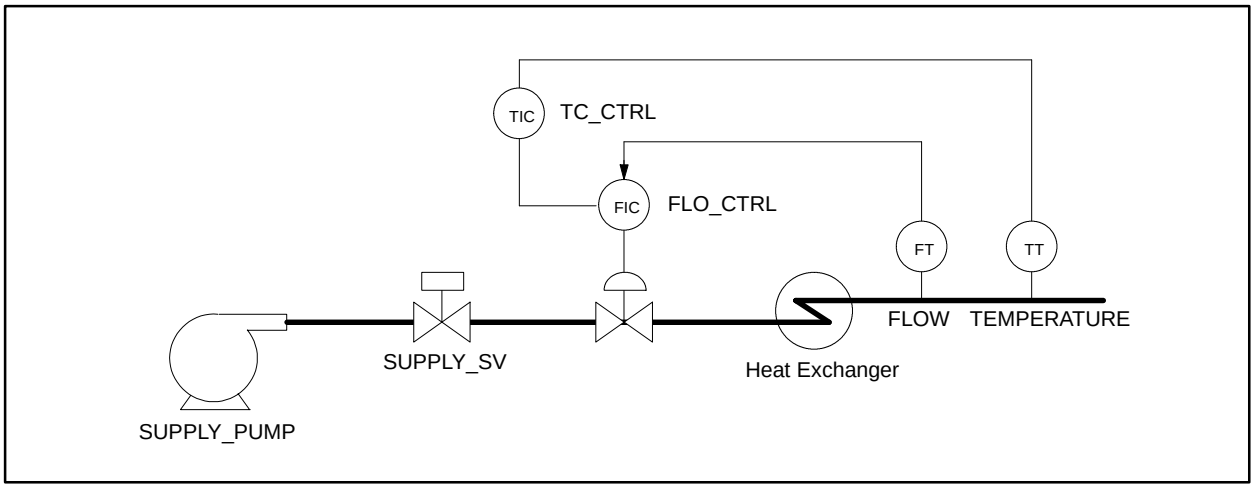

Figure 2-3 Heat Exchanger Example P&ID

Process I/O for the Heat Exchanger

Table 2-3 lists the Series 505 I/O for the Heat Exchanger Example program.

Table 2-3 Heat Exchanger Example I/O

Name	Type	Address	Subtype	Units	Low Range	High Range	Description
Lamp	DO	Y0033					Pilot light
Flow	AI	WX0017	Z		0.0	50.0	Flow rate (fi103)
Temperature	AI	WX0018	Z		50.0	250.0	Temperature (ti103)
Supply_rcv	AO	WY0025	Z				Flow control valve
S_pump_rv	DI	X0002					Supply pump run verify
S_sv_ols	DI	X0001					Supply_sv OLS
S_pump_cmmd	DO	Y0010					Supply pump start command

Chapter 3

Programming Hints

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3.1 Organization of APT Logic

Understand the Logic Structure

When APT generates Relay Ladder Logic (RLL) for Series 505, or Statement List (STL) for S5, the logic sequence follows the organization shown in Figure 3-1. Be aware of this logic sequence when you design your program code to ensure that execution occurs when you expect it.

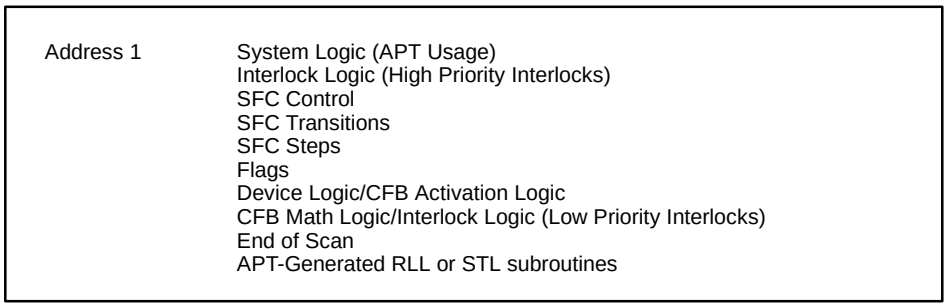

Figure 3-1 Organization of APT Logic in RLL or STL

3.2 Math Hints

Avoid Making Same Comparison Twice

You can improve performance in the controller by not testing a condition repeatedly. Test the condition once and assign the condition to a boolean entity; then test the boolean entity (Figure 3-2).

Do This...	Not This...

B := (I = 1)
If (B) Then
...
...
...
Endif
 	
If (B) Then
...
...
...
Endif;
	If (I = 1) Then
	...
	...
	...
	Endif;
	
	If (I = 1) Then
	...
	...
	...
	Endif;

Figure 3-2 Example of Reducing Math Comparisons

Use Boolean Logic when Possible

In RLL and STL, controllers execute boolean logic faster and require less code than IF/THEN/ELSE statements (Figure 3-3); use boolean logic instead of conditional statements.

Do This...	Not This...

b := (z or q or r);	If (z or q or r) then
	b := true;
	Else
	b:= false;
	Endif;

b := (temp > 25.0);	If (temp > 25.0) then
	b := true;
	Else
	b:= false;
	Endif;

Figure 3-3 Use Boolean Logic for Speed

There are times when your application requires that a boolean entity remain turned on (latched). See Figure 3-4.

Do This...	Not This...

b : = (b or (temp > 25.0));	If (temp > 25.0) then
	b := true;
	Endif;

Figure 3-4 Logic Differences between If/Then and Boolean Logic

Write Clear and Readable Code

In Figure 3-5, calculation A is processed as quickly as calculation B, but is easier to read and to debug. Although calculation B requires less code, it is better that your code be readable and understandable.

A	B
Do This...	Not This...
C = A + B; E = C * D; G = E – F;	G = ((A + B) * D) – F;

Figure 3-5 Write Code Clearly

Use parentheses freely to make math code easy to understand (Figure 3-6). The use of parentheses also removes any doubt about the order of execution.

Do This...	Not This...

If ((not (t)) and S) then
...
...
...
Endif;
	If not t and S then
	...
	...
	...
	Endif;

Figure 3-6 Use Parentheses in Math

Indent program code when appropriate (Figure 3-7). This makes it easier to identify code sections, such as IF/THEN statements.

Do This...	Not This...

If (B) Then
  If (C) Then
  ...
  Else
  ...
  Endif
Else
  B : = Z;
Endif;
	If (B) Then
	If (C) Then
	...
	Else
	...
	Endif
	Else
	B : = Z;
	Endif;

Figure 3-7 Indent Math Code

Use Event Math CFBs

The 545, 545L, 555, 565/565T/565P, and 575 controllers allow no more than 32 cyclic SF programs to be queued at a given time. If you need additional timed-cyclic events, incorporate event math blocks in your program and use an RLL or STL timer to time the cycles. Refer to Figure 3-8.

```
                    Declarations
Timer (slow or fast)        BLK01_TMR
Boolean entity              BLK01_OVRN


                      Blocks
Event Math CFB              BLK01


BLK01_TMR.ENABL     :=  TRUE;
BLK01_TMR.RESET     :=  NOT(BLK01_TMR.TOUT);
BLK01_OVRN          :=  (BLK01_TMR.TOUT AND BLK01_TMR.ENABL)
                        OR
                        (BLK01_OVRN AND NOT (BLK01_TMR.TOUT));
BLK01.ENABL         :=  (BLK01_TMR.TOUT OR BLK01.ENABL)
                        AND
                        NOT (BLK01.ENABLD);
```

Figure 3-8 Use Event Math Blocks to Create Cyclic Events

You can check the boolean entity, an optional part to the code **BLK01_OVRN,** to see if the event is overrunning.

Use Active Versus Continuous Option

When you want boolean math to be executed continually, use the **Active** option, as opposed to the **Continuous** option with enabling. This requires less code and ensures that the math processing is not turned off.

RLL Math Is Processed Faster than SF Math for Series 505 Controllers

The Series 505 controller processes RLL math much faster than SF math. When possible, use RLL functions and procedures for math calculations. The *SIMATIC APT Programming Reference (Graphics/Math) Manual* lists RLL-only and SF-only math functions and procedures. For those procedures that can be programmed in either RLL or an SF program, APT generates and uses RLL logic.

For Series 505 Controllers, if you use just one SF math function or procedure requiring SF programming in a calculation, the entire calculation is done in an SF program. The simple calculation in Figure 3-9 requires SF programming because a single variable F is a real number.

```
                                C = A + B
                                E = C * D
                                F = F + 2.0

Programming Allowed    Operators    Integer Variables    Real Variables

RLL                    +, -, *      A, B, C, D, E
SF                                                       F
```

Figure 3-9 Calculation Requiring SF Program

For Series 505 Controllers, use the PRAGMA statement in a math block that you are designing to be RLL or SFPGM only. If you inadvertently use SFPGM code in math that you intend to be RLL only, and vice versa, a compile error is generated. The PRAGMA statement is described in the Math Language Overview chapter of the *SIMATIC APT Programming Reference (Graphics/Math) Manual.*

Use the **Report** option to see whether APT places the code for a calculation in RLL or an SF program.

1. At the **Program Content** level of the hierarchy, place the cursor on **Object** and select **Report**.

2. When prompted for the type of report, select the following option: **SFC/CFB math to P/C address**.

3. Examine the report. If the report does not show that a calculation is assigned to an SF program, it has been coded in RLL.

Consolidate CFB Math for Series 505 Controllers

To reduce controller overhead, consolidate Series 505 SF math into as few CFBs as possible. For example, it is preferable to use one math block instead of a combination of the Summer, Subtractor, Multiplier, and Divider blocks (Figure 3-10).

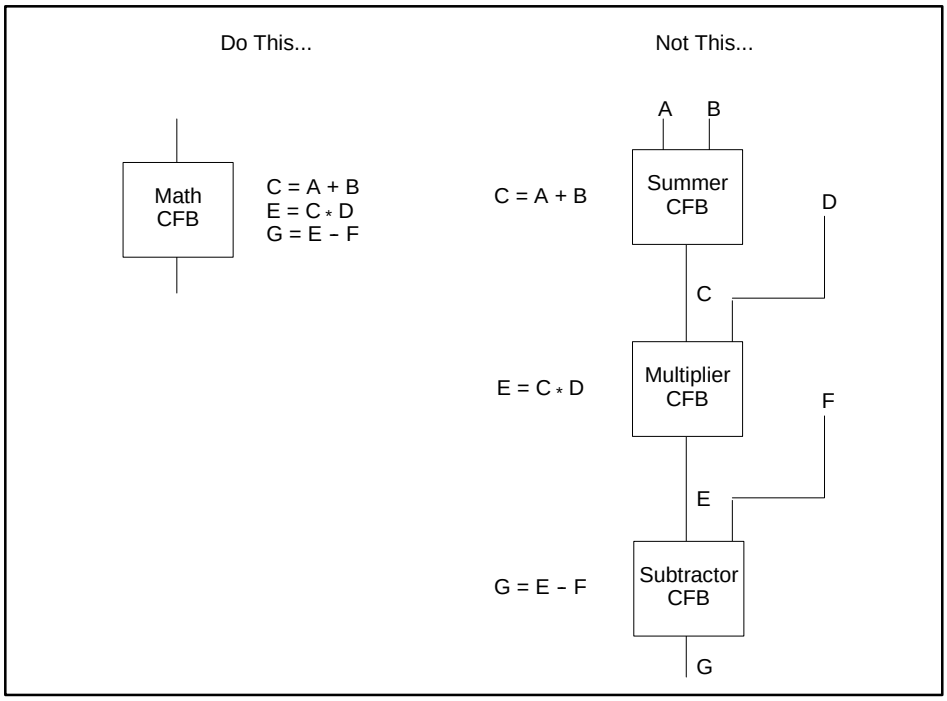

Figure 3-10 Consolidate CFB Math

Consider these other points when you create code for math calculations.

- Except for comparisons (=, <, >, < >), real number calculations are always done in an SF program. Associated math calculations for PID loop and analog alarm processing are also done in SF programs.
- Arrays with simple number indexing (array [1]) are placed in RLL. An array with an index composed of an expression (array [i])is placed in an SF program.
- Read bit 14 in Status Word 1 (%STW01) to see if the RLL scan is overrunning. When the bit is true (= 1) the scan is too short to execute the entire program in the designated scan time. The variable **Program_name.TSCAN** contains the time in milliseconds for the last scan.
- Do not mix RLL math functions and procedures with SF math functions and procedures. The program does not compile and the validation utility does not catch this error.

3.3 SF Program/Loop/Analog Alarm Hints for Series 505 Controllers

How Priority for SF Tasks Is Determined for Series 505 Controllers

You cannot easily predict the order in which the Series 505 controller processes loops, analog alarms, and other blocks that use SF programs. The controller follows these rules.

- PID loops and analog alarms have the highest priority for processing. Refer to the appropriate programming reference manual for your controller for information about when associated math for loops and analog alarms is processed.

  The processor program execution time dedicated to associated math SF programs is determined by the time allocated to loop and analog alarm processing. For the 545, 545L, 555, and 575, these time slices are user configurable. When you set the time slices, you are also affecting the length of the overall controller scan. Shorter analog time slices reduce the overall scan time and the I/O is updated faster. Typically, you want to reduce the analog portion of the scan as much as possible to reduce the overall scan time. However, do not allow too little time for the analog portion: Loops and analog alarms will begin to overrun, and the time for SF programs to execute after scheduling will be longer.

  For the 565/565T/565P, 60% of the processor's program execution time is allocated for loops and 15% for analog alarms.

- Cyclic SF programs have the second highest priority for execution. A cyclic SF program is executed when the input to the RLL SF program instruction transitions from off to on. When the cyclic SF program has terminated, it is automatically re-queued for execution based on the programmed cycle time (0.5 second increments). This process continues as long as the input to the RLL SF program instruction is on. When the input turns off, the cyclic SF program is removed from the queue.

  For the 545, 545L, 555, and 575, you can adjust the cyclic SF program time slice to your own specifications. For the 565/565T/565P, the processor allocates approximately 8% of the program execution time to cyclic SF programs.

- Priority and non-priority SF programs have the third highest priority for execution. APT allows you to create only non-priority (normal) SF programs.

  The difference between high and low priority Interlock blocks is their position in RLL. All high priority blocks are placed near the top of the RLL. If the code in the high priority Interlock block creates an SF program, a normal SFPGM is created and called from RLL.

  APT creates two priority SF control blocks for each unit. The first control block is used to scale unfiltered analog inputs and most math CFBs (exceptions: Interlock and Math). The second control block is used to scale and filter analog inputs that you have marked as filtered. Both of these control blocks are executed as quickly as possible.

  For the 545, 545L, 555, and 575, you can adjust the time slices yourself. If necessary, you can allocate equal processor time to the two types of SF programs.

  For the 565/565T/565P, the processor allocates approximately twice as much program execution time to priority SF programs as to non-priority SF programs.

Your calculation of an SF program execution time, based on the statement times, is the actual execution time required for the controller to run the SF program. The time from when the SF program is placed in the queue until the execution begins can vary. This wait depends upon the number of SF programs scheduled, how long they take for execution, how long the time slice is, and the priority of other SF tasks scheduled for processing.

Detecting Task Overruns

As the number of loops, analog alarms, and SF programs increases, you need to test your program to see if any of these tasks are overrunning. Create code to check the status of the bits in Status Word 162 (%STW162), shown in Figure 3-11. You can also check status by selecting the PC Diagnostics Cell Aux Function from the APT Debug utility.

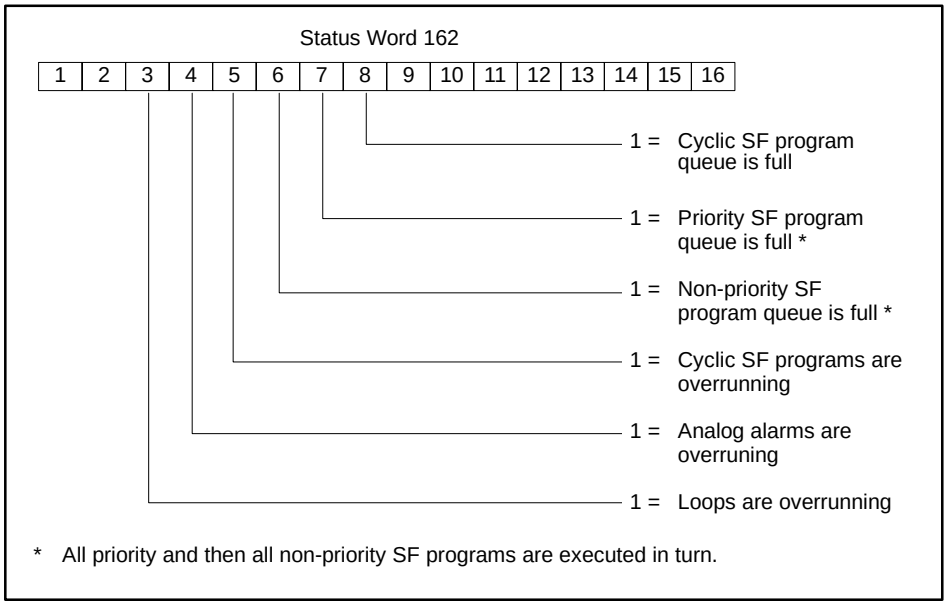
Status Word 162
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
1 = Cyclic SF program queue is full
1 = Priority SF program queue is full *
1 = Non-priority SF program queue is full *
1 = Cyclic SF programs are overrunning
1 = Analog alarms are overruning
1 = Loops are overrunning
* All priority and then all non-priority SF programs are executed in turn.

Figure 3-11 Status Word 162

The 545, 545L, 555, and 575 allow you to queue up to 32 cyclic SF programs at once. If you create more than 32 cyclic SF programs, only the first 32 that are queued will be executed. Check bit 8 in Status Word 162 to see if the queue is full. See the procedure on page 3-5 for a way to create more than 32 cyclic events.

Handling Task Overruns

To correct overruns, consider the following options.

- Increase loop and analog alarm sample times where possible.
- Separate math that can be done in RLL from SF program math.
- Combine several SF programs into one. An example of this is shown in Figure 3-12.

For a 545, 545L, 555, and 575, you can also use the Peak Elapsed Time words. For example, you can check LPET to determine whether or not a loop is coming close to overrunning. If the value in the LPET approaches the sample time, you can increase the loop time slice. Alternatively, you can decrease the other time slices. This reduces the overall scan, allowing the loops to run more often in a given time.

When you determine the base location for SF modules, consider the impact on the controller scan. Update time for an SF module is an order of magnitude faster when you install the module in the local base for a 545, as opposed to a remote base.

If all SF modules cannot be installed in the local base, consider placing low-activity SF modules, such as the ASCII, BASIC, or DCP modules, in a remote base. Locate high-activity modules, such as the NIM or PEERLINK, in the local base.

Correlating Loop and Real Math Processing

You can ensure that the math processing is done at the appropriate time by placing all math calculations for the loop into the associated math section for the loop. The SF program that executes this math executes with the highest priority.

Note these other considerations.

- The controller always executes the split range and scale blocks, in Figure 3-12, as quickly as possible. However, the frequency of execution for code that is processed in the 545, 545L, 555, or 575 analog time slice or the 565/565T/565P controller is determined by a task-queueing algorithm. Frequency depends upon the number of SF programs scheduled, their execution time, priority of other SF tasks scheduled for processing, etc.
- Since APT Rel. 1.4, the algorithm that controls object download affects the execution flow of CFBs. Although the exact order in which blocks are executed is not predictable, the order does not change from download to download.
- In Figure 3-12, execution for the PID block that is graphically connected to the split range and scale blocks requires at least an additional 0.5 second more time than the PID block that contains associated math.
- Additional SF blocks (scale and split range in Figure 3-12) tend to increase the program execution time.

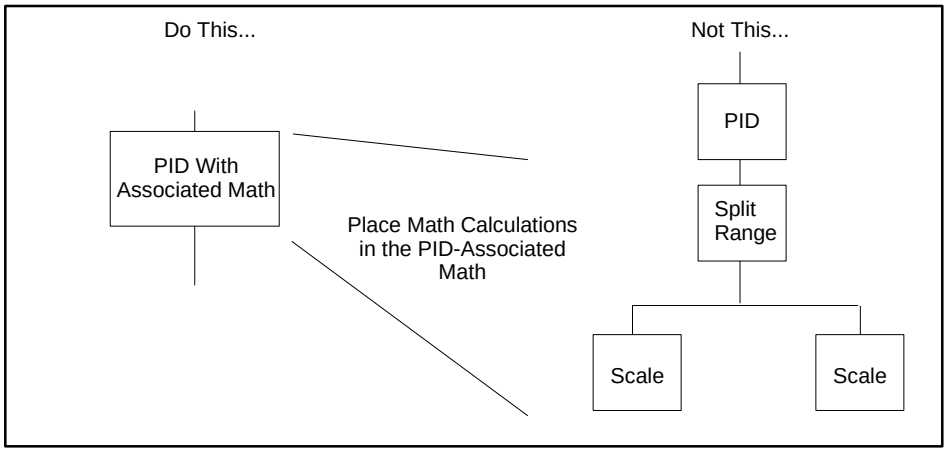

Figure 3-12 Consolidate Math Functions

3.4 Recipe Hints

Avoid Using Boolean Variables as Recipe Elements

Use integers instead of boolean variables as recipe elements. Recipe assignments use excessive code when boolean elements are included.

Use these math function/procedures to move boolean entities to and from recipe elements and boolean arrays.

- BITS_TO_INT, INT_TO_BITS (These operations generate more code in RLL code segments; use PACK_BITS procedure.)
- BITTEST
- BITSET
- BITCLEAR
- PACK_BITS

3.5 Hints for Using Debug

Charts

Define the Debug charts under the chart heading in the Debug hierarchy that has the same name as the SFCs used in the program. In these charts, group all information of interest to you when troubleshooting that SFC.

Remember these functions.

- Press ALT C to select a new chart quickly.
- Use the Monitor Option (press ALT N) to see the values of the data points in the chart.
- Document your chart entries by using comments often where appropriate.
- Use the Animate Option (press ALT I) to see a detailed view of the currently active APT object (SFC, CFB, device, I/O point, declaration, etc.).
- Use the keys for Monitor and Animate to toggle back and forth between a chart and the APT object on which the cursor is placed. This is faster than exiting from either the chart or the object by pressing ESC.
- Press F7 (the function key for split screen) to look inside a CFC or SFC for more information about how the CFC or SFC was programmed.

3.6 Miscellaneous Hints

Guidelines for More Efficient Use of APT

Follow these guidelines to help you use APT most efficiently.

- Use the online Help for quick access to information.
- Validate individual objects frequently as you build your program. Use the Multi-File option to validate several objects at a time.

  Because program- or unit-level validations can be lengthy processes, it is preferable to validate individual SFCs, CFCs, and tables. This is particularly true when you have made only a few changes within one or two objects. You do not gain by validating the entire unit or program, and it takes longer.
- Use the Verify option any time that you want to check for changes that may have been made to the controller program. (Series 505 only)
- Select Force Compile in the Control File and recompile the program if you receive Internal Errors during a compile.
- If you are still developing your program or making a lot of changes, compile the program with the Force Compile option selected.
- Do not select Force Compile when you make changes to only one portion of the program: the system then compiles only those portions of the program that have changed since the last compile.

  If the compile fails because you have incorrectly identified your controller configuration, (i.e., the size of memory or the number of RCCs for a 565), recompile without Force Compile selected after you correct the configuration in the Control File.
- Archive your program frequently to protect against a loss due to a power failure.
- Make changes to a copy of the program when you want to change a program that has been compiled and downloaded to the controller. Consider placing copies of the program on two different hard disk partitions, using one for editing/compiling, the other for debugging.

  You are limited in the Debug features that you can use to test your controller program if you change the source code directly. When you make changes in an SFC, for example, Debug does not display the SFC, although the SFC code is still executed in the controller. All other code can be viewed, but the source and object code may differ.

  Refer to the *SIMATIC APT User Manual* for more information about using Debug.

Avoid Overuse of Timers in SFCs

When you need to use a timer in two or more sequential steps of an SFC, you usually can change the preset and reuse one timer repeatedly (Figure 3-13). Unless you need multiple timers for parallel operations, use this programming practice instead of declaring and using several timers.

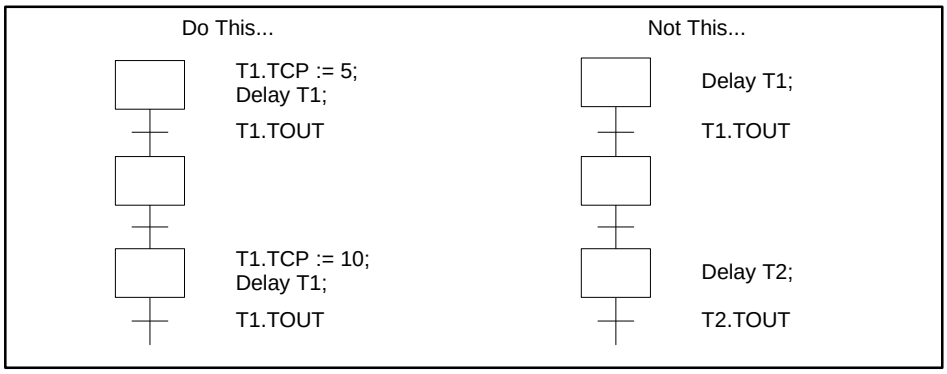

Figure 3-13 Use a Timer More than Once

NOTE: You cannot use the same timer in two consecutive steps of an SFC.

Control Relay Allocation for Series 505 Controllers

Control relays numbered greater than 512 require more controller memory. To conserve memory, APT assigns reference numbers less than 512 to the most frequently used control relays. If you reserve a large number of non-retentive control relays, some of the most frequently used control relays can be assigned reference numbers greater than 512.

Release 6.0 of the 560T/565T/565P has additional RLL instructions that use 1024 non-retentive control relays. The control relays numbered from 56321 to 57344 are no longer available for application programs. Any release of the 545, 555, or 575, which support the same additional RLL instructions, will support the following number of control relays: 4096 for 545L, 32768 for 545 and 555, and 23553 for 575.

NOTE: The 560T/565P controllers have local control relays (C10241–C56320) that can be used in APT programs. These control relays are not completely supported in the 565T, and are therefore not available for use in APT for this controller.

Using Commands, Flags, and Extensions

Command bits, i.e., read-write boolean values, allow you to change the condition of an object. You can control these bits by the following methods.

Method	Device Example	PID Loop Example
Use a command in an SFC	**Lock** *valve_1*;	**Auto** *pid_1*;
Use a command in MATH	**Lock** (*valve_1*);	**Auto** (*pid_1*);
Use an APT flag	**On** (*valve_1*.**RTL**);	**On** (*pid_1*.**RAUTO**);
Use a boolean extension	*valve_1*.**LOCKD := true;**	*pid_1*.**GAUTO := true;**

The command manipulates the APT flag and the boolean extensions in order to control the object. Use the command, rather than the extensions, to control the mode of the object, because APT can overwrite the boolean mode extensions. Use the APT flags and boolean extensions to monitor the status of the object. If you use an APT flag extension, you must use the LATCH, ON, and CLEAR math procedures, described in the chapter on "Math Functions and Procedures" in the *SIMATIC APT Programming Reference (Graphics/Math) Manual*.

Group the Interlock Functions

Place all logic and events that set related devices or CFBs to the not-ready state into the same (interlocked) CFC. During a debug session this enables you to avoid searching for all the various program sections that could set a device to not-ready. You need only check the inputs at the single location in which the **.NRDY** bit is set. One input bit can represent the logic of complex code executed elsewhere. Use a comment to indicate location of the code; refer to Figure 3-14.

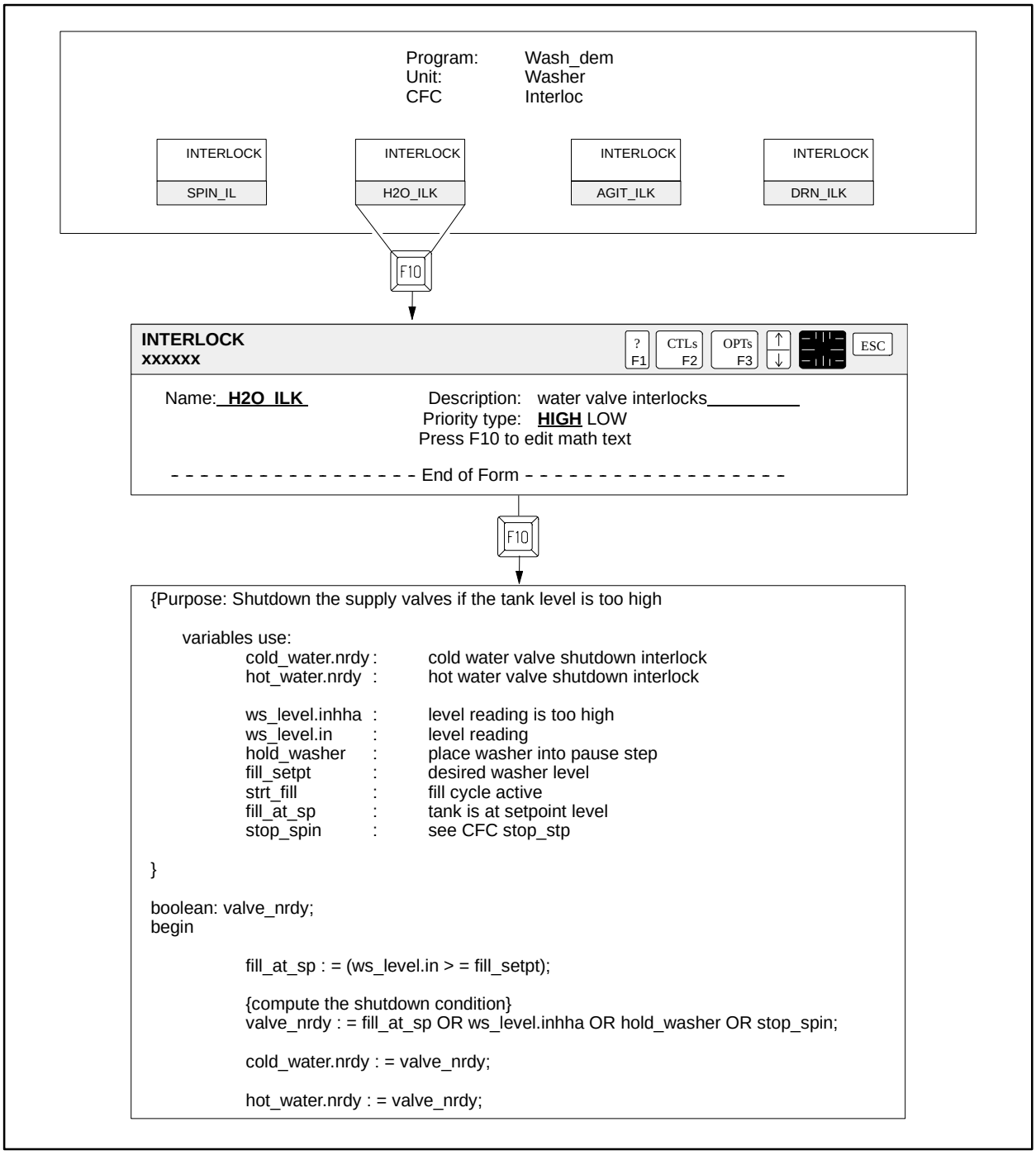
Program: Wash_dem
Unit: Washer
CFC Interloc
INTERLOCK
SPIN_IL
INTERLOCK
H2O_ILK
INTERLOCK
AGIT_ILK
INTERLOCK
DRN_ILK
F10
INTERLOCK
xxxxxx
? F1
CTLs F2
OPTs F3
ESC
Name: H2O_ILK
Description: water valve interlocks
Priority type: HIGH LOW
Press F10 to edit math text
- - - - - - - - - - - - - - - - - - End of Form - - - - - - - - - - - - - - - - - -
F10
{Purpose: Shutdown the supply valves if the tank level is too high
variables use:
cold_water.nrdy : cold water valve shutdown interlock
hot_water.nrdy : hot water valve shutdown interlock
ws_level.inhha : level reading is too high
ws_level.in : level reading
hold_washer : place washer into pause step
fill_setpt : desired washer level
strt_fill : fill cycle active
fill_at_sp : tank is at setpoint level
stop_spin : see CFC stop_stp
}
boolean: valve_nrdy;
begin
fill_at_sp : = (ws_level.in > = fill_setpt);
{compute the shutdown condition}
valve_nrdy : = fill_at_sp OR ws_level.inhha OR hold_washer OR stop_spin;
cold_water.nrdy : = valve_nrdy;
hot_water.nrdy : = valve_nrdy;

Figure 3-14 Example of Interlock Logic

Programming Safe-State SFCs

The RETENTIVE option specifies that an armed safe-state SFC remains armed when a power failure occurs. If you do not include the RETENTIVE option, a power failure effectively disarms a safe-state SFC.

If you define a safe-state SFC with the RETENTIVE option, you do not have to enable the unit to restart the process. If you specify the power failure detection bit as the trigger condition (SSTRIGGER ***program_name*.PWRFL**;), program execution begins with the initial step of that safe-state SFC (assuming that the SFC was armed at the time of the power failure).

Program Download: Redundancy Constraints

The HBU (Hot Backup Unit), or standby unit, presents several points to consider when you download programs.

- For APT, certain incremental program downloads cannot occur with the STANDBY unit ON-LINE. You must set the STANDBY unit to the OFF-LINE state before doing the download.
- When the process is running correctly, one controller is ACTIVE and the other controller is STANDBY ON-LINE.
- A new program can always be downloaded to the ACTIVE controller, but a new program cannot be downloaded to the STANDBY ON-LINE controller.
- For Series 505, a new program with the I/O configuration cannot be downloaded to a STANDBY OFF-LINE controller. A new program without the I/O configuration can be downloaded to the STANDBY OFF-LINE controller.

If You Need More L-Memory or Faster RLL Execution for Series 505 Controllers...

When you need to reduce RLL scan time in Series 505 controllers, consider these options.

- Force math calculations to be made in an SF program instead of RLL. The consequences are described on page 3-6.
- Use a faster controller, such as a 545, 545L, 555, 560T/565P, or a 575. The 555 is the fastest controller.
- Use the guidelines suggested in this chapter to make your code more efficient.

When you need to remove RLL code from L-memory, force math to be executed in an SF program. Use the PRAGMA code specifier statement in the math code. This forces the math code into SFPGM code and causes a compile error to be generated if you inadvertently use RLL code in math that you intend to be SFPGM only.

PRAGMA ("SF"); causes math to be executed in an SF program and reduces RLL scan time.

If You Need Faster STL Execution for S5 Controllers...

When you need to reduce STL scan time in S5 controllers, consider these options.

- Use a faster controller, such as a 948. The 948 is the fastest S5 controller that APT supports.
- Use the guidelines suggested in this chapter to make your code more efficient.
- Use global variable instead of passing parameters into a subroutine.

Program Recovery from Controller Power Loss

If there is a possibility of power loss to your controller, provide alternative uninterruptible sources of power for your system. At the least, make sure that the battery backup to your controller is good. If the controller loses power and the battery switch is off or the battery is low, the APT program is lost. You must download the program again. This section describes how the APT program responds to a power loss to your controller.

Units. All units become inactive and remain inactive until the power returns. When power returns, each unit starts up in the initial step of the main SFC. If you want to control the response to a power loss, use a retentive safe-state SFC. Place an SSARM command in the initial step of the main SFC. Use the *prog_name*.**PWRFL** extension as a trigger in the SSTRIGGER command.

SFCs. When a unit is disabled by a controller power loss, or when the *unit_name*.**ENABL** bit is set to false, all active SFC steps in that unit become inactive. On a return from the power loss, the initial step in the main SFC becomes active.

CFBs. Continuous function blocks enter the state that they were in before the power loss.

Declaration Values. For Series 505, retentive boolean entities retain their values, the function suggested by their name. Other boolean declarations are cleared. All S5 booleans are retentive and retain their values. Real and integer variables remain at their last state. Constants are not changed.

I/O. Outputs are cleared and a full controller scan takes place before they are written again.

Devices. For Series 505 controllers, unless the Uninterruptible Power Supply option in the compile control file is selected, power-fail recovery logic for devices is included. After returning from a power loss, all devices go to their safe-state position. For Series 505 and S5 controllers, all devices go to their safe state positions and are unlocked upon return from power loss.

For Series 505, the **.PFAIL** control relays, shown in the figures of the Device Operation Appendix of the *SIMATIC APT Programming Reference (Tables) Manual*, are included in the code if you do not select the **UPS** option in the Compiler Control File. This means that the device logic copies the states of the device status control relays into a V-memory location every scan. After the recovery from a power loss, this data is copied from the V-memory location back into the appropriate control relays.

For Series 505, if you do select the **UPS** option in the Compile Control File the states of the device status control relays are not copied into V-memory. After recovery from power loss all devices enter the de-energized state and are unlocked. This action is not controlled by controller logic.

For S5 controllers, since memory is retentive, the states of the device status bits are not copied into **.VFLAG**. After a power fail, the status of the devices is still in memory and the controller performs a controlled transition to the safe-state condition; all devices enter the de-energized state and are unlocked.

3.7 Configuring Devices

Configuring Simple Devices

It is unnecessary to enter simple devices, (e.g., no feedback or always manual or automatic) into the Device Definition Table. Instead, you can define your own device with declaration tables, I/O tables, and math blocks. Enter a name in the I/O Symbolic Name Table to represent the device and then use math statements to control the actions of the device. This can save you approximately 100 words of L-memory, 10–13 control relays, and two timers for Series 505 controllers or 200 words of STL code, 10–13 flags, and two timers for S5 controllers.

You may want to program a device such as a simple pump or valve as a digital output (DO), and not as an APT device, under these conditions:

- The device starts quickly, has no feedback, and you do not care about a traveling state.
- The device always operates in manual mode.
- Your application does not require the controller to control the device through an interlock.

Program a device as an APT null feedback device (e.g., VSN, MSN) when these conditions are true:

- There is no feedback from the device, but you want to allow the device a certain length of time to react to a command. A wait state is required before logic execution continues. You can show a traveling state.
- Your application requires the controller to determine when the device cannot operate through an interlock. The operator can still operate the device manually.

The APT VSN, for example, provides the **.OPND** extension that becomes true after a specified period of time. The **.NRDY** extension interlocks to the fail-safe condition.

You can also use the user-defined devices VUD, MUD, CUD, and PUD. These devices use two timers and create extensions in V-memory and C-memory for Series 505 controllers, or DB-memory for S5 controllers. Use math blocks for your customized math for controlling the devices.

Using Pseudo Devices

You can define a device to control any flow path. Use math logic to operate a combination of valves and motors. All feedbacks can be ANDed to create a single feedback. See Figure 3-15.

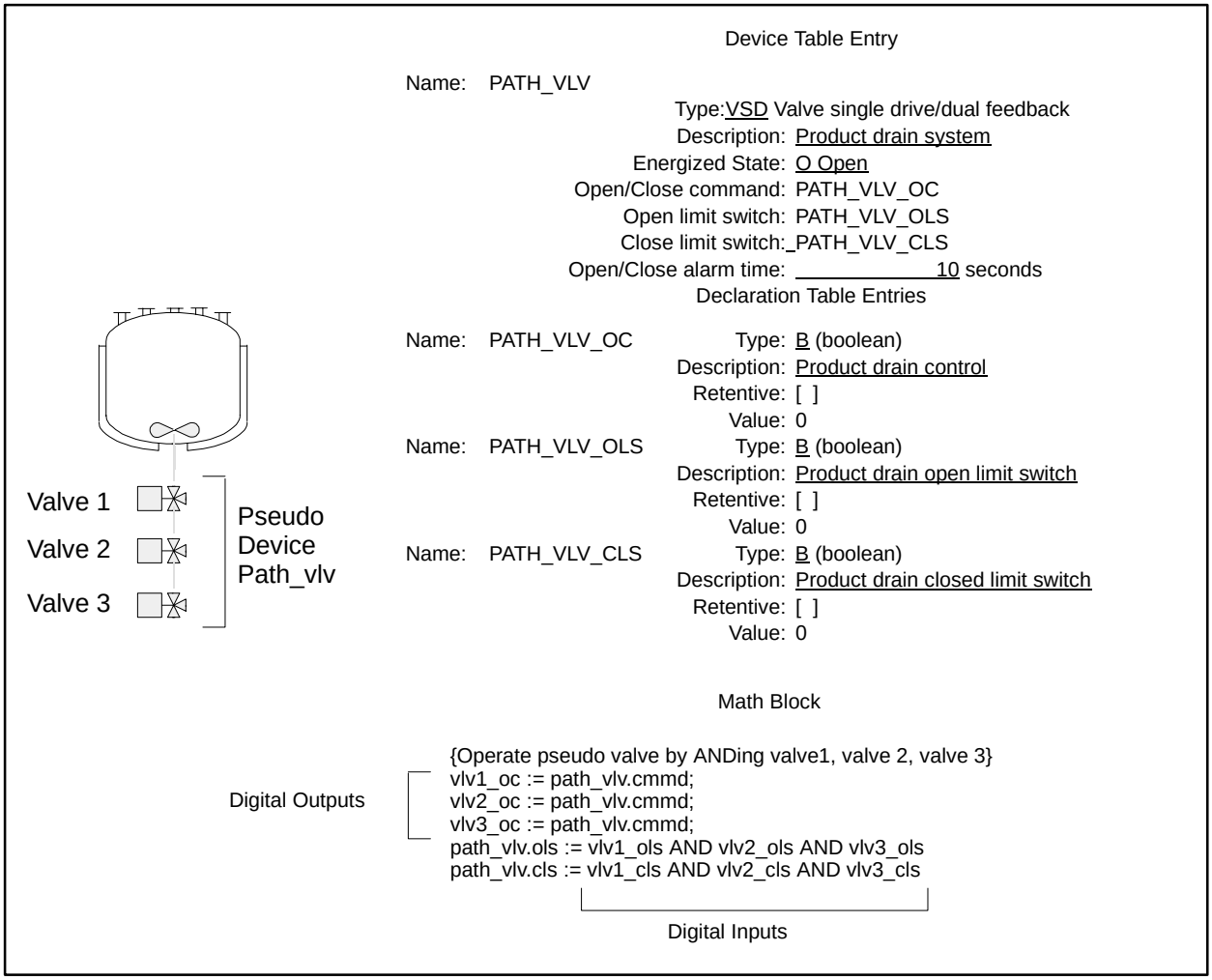

Figure 3-15 Example of a Pseudo Device

3.8 Table and I/O Hints

Working in Tables

Use the SPLIT-SCREEN function. As you work on a table, you can display a report to help you fill out the table. Use the SORT function to organize table elements. You can sort by type, by name, by description, or by address.

Configuring Unlisted I/O Modules for Series 505

When you need to configure a module that does not appear in the APT Module Definition Table for Series 505 controllers, select the User Module.

Configuring the PEERLINK Module for Series 505 Controllers

To configure the Peerlink Module in a Series 505 controller, enter the appropriate information in the Module Table. Then, reserve at least sixteen V-memory locations in the Compiler Control File for each node on the Peerlink network. In addition, you must assign values to the .ALO and .AHI I/O points that represent the starting and ending addresses of the Peerlink Table.

Refer to the user manual for the Series 505 Peerlink Module for more information about configuring this module.

Configuring the HSPI and HSC Modules for Series 505 Controllers

Module configuration for the Series 505 HSPI and HSC Modules is not fully supported. No channel setup data that you enter is sent to the module.

The WY memory locations for an HSPI Module with the prefix HSPI1 can be initialized in an event math block as shown below.

```
{                                    1 1 1 1 1 1 1}
{Bit position:          1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6}
HSPI1_C1SET:=   #2# 0 0 1 0 1 0 0 0 0 0 1 0 0 0 1 1;{Channel 1 Setup}
HSPI1_C2SET:=   #2# 0 0 1 0 1 0 0 1 1 1 0 0 0 0 1 1;{Channel 2 Setup}
HSPI1_C1P1:= 32000;                                  {Channel 1 Preset 1}
HSPI1_C1P2:= 1;                                      {Channel 1 Preset 2}
HSPI1_C2P3:= 32000;                                  {Channel 2 Preset 3}
HSPI1_C2P4:= 1;                                      {Channel 2 Preset 4}
```

Refer to the user manuals for the Series 500 High Speed Pulse Input Module and the Series 505 High Speed Counter/Encoder Module for more information about configuring these modules.

Configuring ET200

ET200 I/O racks can be used by both controller families. For Series 505, you configure ET200 from the Module Editor. You can define the ET200 rack with existing APT modules or by configuring a User Module. If you have an S5 controller, you must program the IM308 card through the front panel of the card using COM ET200, the software that configures the IM308 card. You cannot configure the IM308 card through APT. After you configure the IM308, you can bring your ET200 I/O into APT by defining them in the I/O Table. The I/O Table will accept the following addresses: IW0–126, QW0–126, PW0–254, and OW0–254, but will not accept page addresses.

3.9 OSx Hints

Selecting APT Object Names

APT allows you to translate APT names into OSx tags. Detailed instructions for marking APT names and translating them are given in the *SIMATIC APT User Manual*.

APT permits you to use names having more than twelve characters. However, OSx uses names of twelve characters or less. When APT translates a name, as many characters as possible are used in the OSx name. For example, these names are translated as follows.

APT Name	OSx Name
HORN	HORN
SIREN_23	SIREN_23
WATER_VALVE	WATER_VALVE

APT does not permit you to mark all the following water pump designations for translation because the OSx names for the water pumps would be identical.

APT Name	OSx Name
WATER_PUMP_331	WATER_PUMP_3
WATER_PUMP_332	WATER_PUMP_3
WATER_PUMP_333	WATER_PUMP_3

For the APT names representing Water Pumps 331, 332, and 333 to be translated into unique OSx names, remember the twelve-character OSx requirement when you select the APT names. See the example below.

APT Name	OSx Name
WTR_PUMP_331	WTR_PUMP_331
WTR_PUMP_332	WTR_PUMP_332
WTR_PUMP_333	WTR_PUMP_333

When you mark names for translation, APT allows you to choose different object names to be used by OSx. These names may be altogether different from the APT names that you used. However, if you choose unique twelve-character APT names when you create your APT program, you may save time and avoid confusion when you translate them for OSx.

Selecting Array Names

Observe the same twelve-character name requirements when you create an array. The array elements shown below cannot be fully translated because the OSx names would be identical.

APT Name	OSx Name
SEQARY_MAPS[1]	SEQARY_MAPS[
SEQARY_MAPS[2]	SEQARY_MAPS[

An error occurs when you mark the second name above for translation. The array number (in brackets) is part of the name; observe the OSx twelve-character name requirements, as shown below.

APT Name	OSx Name
SEQ_MPS[1]	SEQ_MPS[1]
SEQ_MPS[2]	SEQ_MPS[2]

Selecting Recipe Names

Observe the same name-length requirements for recipe names. The recipe elements shown below cannot be fully translated because the OSx names would be identical.

APT Name	OSx Name
WORKING_REC.TEMP	WORKING_REC.
WORKING_REC.MIXT	WORKING_REC.

Use the following recipe name conventions instead.

APT Name	OSx Name
WR.TEMP	WR.TEMP
WR.MIXT	WR.MIXT

Selecting Unit Names

Although APT can differentiate between identical names in different units, OSx cannot. The names shown below cannot be translated because the OSx names would be identical. An error occurs when you mark the second name for translation.

APT Name	OSx Name
TK_LEVEL (Used in tank 1 unit)	TK_LEVEL
TK_LEVEL (Used in tank 2 unit)	TK_LEVEL

Solution. Use similar APT names, but unique OSx names. Choose short APT names that you can easily modify for the 12-character OSx name requirements. Refer to the example below.

APT Name	OSx Name
TK_LEVEL (Used in tank 1 unit)	TK1_LEVEL
TK_LEVEL (Used in tank 2 unit)	TK2_LEVEL

Other examples of appropriate OSx names are the ISA names used in your P&ID drawings.

Alternative Solution. Use unique APT names and unique OSx names. An alternative is to use unique APT names that can be translated for OSx without error. Refer to the example below.

APT Name	OSx Name
TK1_LEVEL (Used in tank 1 unit)	TK1_LEVEL
TK2_LEVEL (Used in tank 2 unit)	TK2_LEVEL

The alternative solution makes unit copies in APT less simple to do because the general term *LEVEL* in Unit 1 is replaced with the specific term *TK1_LEVEL*. When Unit 1 logic is copied to Unit 2, the name *TK1_LEVEL* must be replaced with *TK2_LEVEL*. However, if you choose unique APT names when you create your APT program, you can save time and avoid confusion when you translate them for OSx.

Animating Non-Standard Symbols

Often there are times when you need symbols with forms and animations that are not standard in the OSx library.

- A control valve symbol animates the bonnet of the valve to red (manual) or green (automatic) indicating the mode of the associated PID loop.
- A control valve symbol animates the body of the valve to red (closed) or green (not closed) indicating whether the control valve is opened or not.

To achieve these animations, you can create a single integer and manipulate it from the associated math of the corresponding PID loop to provide the status information for OSx. In this case, two tags may be needed for each PID loop created in APT.

Validation Failure

If the tag installation procedure fails, the problem is often due to an initial value that falls outside the H_RANGE and L_RANGE values. For a temporary correction, you can edit the INSTALL.TAG file and either change the initial value or the high and low ranges. Refer to Appendix A of this manual for a description of the INSTALL.TAG file.

Unless you make the correction in the APT program and then recompile, however, the error will continue to occur during installation.

3.10 Relating APT and the Non-OSx Operator Interface Database

Chapter 7 describes the link between the operator interface and the application program. The creation of this link involves four major steps.

1. Assign addresses to objects.
2. Mark objects for translation. Select objects that are to be used by the operator interface and that must have unchanging controller addresses.
3. Compile the program. Create a file that contains tag data.
4. Translate the tags. Place the tag data into a formatted database that can be used by the operator interface.

You must follow each step for any operator interface. For OSx, all four steps can be done by selecting the appropriate option while you are executing APT.

For a non-OSx operator interface, you can do Steps 1–3 while executing APT. Step 4 is a manual procedure that requires you to enter data into the database used by the operator interface. The format for the database depends upon the operator interface that you use. One attribute that must appear in any operator interface database is the object's address in the controller.

3.11 Recommendations to the CVU1000/10000 User

A Series 505 controller can have a CVU1000/10000 operator interface; this feature is not currently supported for S5. The default displays created by the CVU for loops and analog alarms assume that all loop/analog alarm information is located in Series 505 S-memory. Enter X in the **Map tuning and alarm data to S-Memory** field of the PID form in order to use the default CVU Loop Tune Page for changing the tuning parameters or outputs. Also, use the user-defined address to prevent the loop and analog alarm addresses from changing.

Chapter 4

APT and Controller Memory

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4.1 Overview

Source Code

When you compile your program, APT uses the instructions and objects that you have defined to create RLL and SFPGM for Series 505, or STL for S5. To enhance scan performance, the APT program includes an END statement at the end of the RLL for Series 505 controllers.

After you download a successfully compiled program to the controller, do not make changes to that version of the program. If you want to enhance the program, copy the program and make changes to the copy. You can put copies of the program on two different hard disk partitions, using one for editing/compiling, the other for debugging.

> **⚠ WARNING**
>
> **Debug allows you to modify the contents of variables in the controller. However, if the re-compiled program has not yet been re-downloaded, the addresses the compiler assigned to the items you edited are not yet downloaded in the controller. The address of an edited object may not be what you think, and consequently your modifications could have unpredicted results.**
>
> **Modifying re-compiled objects with Debug could cause unpredictable operations that could result in death or injury to personnel and/or equipment damage.**
>
> **Fully understand what changes have been made to an APT object before modifying it with Debug.**

APT supports limited debugging of a changed or non-APT program. If the program has been changed, APT warns you that the program in the controller does not match the source code, but allows you to debug the program in the controller. If the program you wish to edit does not match the program in the controller, or if the program was not originally created in APT, you will only be allowed direct address capabilities in Debug. If an SFC has been edited, you cannot debug that SFC.

Downloaded Program

After you have a downloaded program in the controller, do not modify the downloaded program unless you fully understand the program logic. In addition, do not change the memory configuration of your controller after you have downloaded an APT program to the controller.

> **⚠ WARNING**
>
> **Incrementally downloading an APT program to the controller affects the current operation of your application.**
>
> **A change in operation of your process could cause unpredictable operations that could result in death or injury to personnel and/or equipment damage.**
>
> **To minimize risk when downloading an APT program, changes should only be made by qualified personnel who are fully aware of the possible consequences of any program modifications.**

If your controller is a Series 505, use the Verify Option to check the program created by the last successful compile against the program in the controller. The verify option indicates discrepancies caused by changes to the program in the controller, but does not check contents of reserved memory areas. The Verify Option is not supported for S5.

4.2 Memory and I/O Usage

Overview

When the program is compiled, APT uses the controller memory at the first location of each type (i.e., SFPGM1, V1 for Series 505; FB1, DB3 for S5) unless you reserve memory in the Compiler Control File for Series 505 controllers. If you reserve memory, APT program use begins at the first location after the reserved area. For example, if you reserve 100 V-memory locations for a Series 505 controller, the APT program uses V101 and above. For S5 controllers you reserve the numbers for the reserved memory, and APT does not use these areas. If you reserve DB 6, 7, 10 and 160-165 then the APT program will not use these DBs that you listed.

NOTE: If your application requires additional logic above and beyond the code created with APT, then reserve APT memory. Although APT allows you to reserve memory for your own use, this is meant only for special cases and should be attempted only by experienced controller users.

Reserving Memory

You can reserve any type of controller memory for your own use in the Compiler Control File. During the compile, APT does not use these specified areas when assembling the object code for download.

After you have successfully compiled a program and begin to download APT, APT establishes the controller memory configuration. Any reserved areas remain untouched, and the APT program is inserted outside the reserved areas.

Guidelines for Series 505 Controllers

If you need to reserve SF programs or SF subroutines, be certain that you also reserve enough Series 505 S-memory (in words) in the Compiler Control File to allow room for the SF programs or SF subroutines that you reserved.

If you configure a loop or analog alarm in APT, follow these guidelines.

- Reserve the number of loops or analog alarms that you need in the Compiler Control File.
- Use the user-assigned addresses for the loops (%LOOP) or analog alarms (%AALM).

If you configure a loop or analog alarm in TISOFT, follow these guidelines.

- Reserve the number of loops or analog alarms that you need in the Compiler Control File.
- Reserve enough S-memory (in words) in the Compiler Control File to allow room for the loops or analog alarms that you reserved.

⚠ WARNING

Many tools, including TISOFT for Series 505 controllers, allow you to change the controller memory configuration of an APT program after the program has been downloaded to the controller.

Changing the controller memory configuration may result in unpredictable operations that could result in death or injury to personnel and/or damage to equipment.

Do not change the controller memory configuration of an APT program using TISOFT; use APT instead. In APT, you can get the memory configuration that you want either by analyzing your reserved memory and making adjustments, or else by analyzing your memory usage, which is shown in the Compiler Control File, and then adjusting your coding methods (RLL versus SFPGM, V- versus K-memory, and so forth.)

Changing Values in Memory

After you have a program downloaded to the controller, you need to take some precautions before you attempt to change values.

Constant values should be set only from within APT. Real and integer values can be set as constants in the Declaration Table. If you need a Boolean constant, use the literal values, true and false.

⚠ WARNING

Many tools, including Debug, MAITT, TISOFT, and STEP 5, allow you to change the values of APT constants in the controller after the program has been downloaded to the controller.

Changing the value of APT constants could cause unpredictable operations that could result in death or injury to personnel and/or damage to equipment.

Never change the value of an APT constant by any other method than editing, re-compiling, and downloading the APT program.

Variables change value during the course of program execution. You can use the APT Debug Utility to change variables, but any changes should be made only by qualified people who understand the APT program.

Initial values of variables are set during download. These variables can be changed at any time by the program or with TISOFT or the APT Debug Modify Option. APT does not reset the initial values of variables unless the program is downloaded again.

Forced elements in Series 505 controllers cannot be changed until they are unforced or forced to a different value. Forced elements remain forced when you download a new program to the controller unless you clear the controller first in the Download Menu.

Reserving I/O Locations in Series 505 Controllers

If you want to configure a Series 505 or Series 500 I/O module in a base, it must be configured in the Module Definition Table. This must be done even if you do not want to define each of module points with APT symbolic names.

After an I/O Module is placed in the Module Table, you can reference the I/O points with direct controller address (e.g., %WY1, %X12...).

For Series 505 controllers, APT locates the last I/O address used by an I/O Module in a channel and uses the remaining points as overflow CRs, if necessary. If you need to conserve memory, eliminate gaps in your I/O addresses where possible. Configure modules consecutively beginning with low starting addresses.

To conserve memory and to save the need for additional RCCs (multiple channel controllers), APT uses any unconfigured I/O locations as overflow CRs. This is transparent to your program. (For multiple channel controllers, each RCC card contains two I/O channels. Each channel contains 1024 configurable I/O locations, 768 non-retentive CRs, and 256 retentive CRs.)

⚠ WARNING

TISOFT and other tools allow you to change the I/O configuration of your controller. During the APT download, APT will overwrite the memory and I/O configuration in your controller with those specified in the Compiler Control File and the I/O Module Table. APT uses certain unconfigured Y locations to supplement requirements for CR locations.

Changes to the I/O configurations that are in use by APT as supplemental CRs could cause unpredictable operations that could result in death or injury to personnel and/or damage to equipment.

Do not use TISOFT or any other external utility to change the I/O configuration on your controller.

Determining Memory and I/O Usage

After a successful compile, the **compile.rpt** lists the amount of each memory type that is used to create the object code for a Series 505 controller or S5 controller. For a Series 505 controller, this report also includes information on retentive and non-retentive CRs and the number of Ys that are used as CRs (overflow CRs).

To obtain information about the controller addresses that are used in the program, create a report on the Object file. The APT Symbol Name to P/C Address Report indicates the exact P/C locations used to store the APT variables.

Loops and Analog Alarms

For both Series 505 and S5 controllers, if you use a P or PI loop, the Derivative time is set to zero on each scan. If you use a P or PD loop, the Integral time is effectively set to infinity on each scan to negate the integral portion of the PID equation.

If you want to change the loop type, you must use APT and recompile and download the program again.

For Series 505 controllers only, if you use any Standard or Advanced CFB, the loop automatically includes one SFPGM to be called from PV, SP and OUTPUT. When you add the Associated Math option, you create additional special function code. As a result, a large number of loops can cause loop overruns if you use small sample times.

For both Series 505 and S5 controllers, the Dead Time Compensator, Feedforward Output Adjust and Feedforward Setpoint Adjust typically require larger sample times than other CFBs. These blocks automatically include a Lead/Lag simulation which occurs on each scan. (The Feedforward Setpoint Adjust can be programmed without the Lead/Lag option).

For Series 505 controllers, if you do not select the **Map Tuning and Alarm Data to S-Memory** field of the PID form, all Loop and Analog Alarm information (e.g., setpoints, tuning parameters, etc.) are stored by APT in V-memory and written into S-memory. Any attempts to change S-memory with an external device (LAM, TISOFT, etc.) are overwritten. You can use the APT Symbol Name to P/C Address Report to determine the V-memory locations for the Loop and Analog Alarm values.

For S5 controllers for loops and analog alarms, set your sample time to a reasonable value. The sample time cannot be less than the cyclic scan time. The loop calculations occur either with each scan or when the sample time is reached.

For an S5 controller, only scaled analog inputs and real values can be used as the process variable (PV). Analog inputs are scaled unless you select **NO SCALING** in the I/O form. See the chapter called "Math Functions and Procedures" in the *SIMATIC APT Programming Reference (Graphics/Math) Manual* for a description of the bit-shifting that is performed when you scale an S5 analog input. If you have an integer input to a loop, you can perform an int_to_real calculation on the input before it is sent to the loop. Use the result of the int_to_real as the process variable in the loop.

Chapter 5

Dynamic Program Simulation

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5.1 Testing the Application Program

There are three general approaches to testing the application program.

- Manual testing
- Repeatable logic testing, based on software routines
- Dynamic simulation

Manual Testing

As you develop your application program, the first testing task consists of the basic manual tests. In these tests, you change the digital and analog inputs manually and observe the results. You can do hardware checks, such as throwing switches or turning dials, and monitor the results in APT to test inputs to the controller. You can make software changes, such as using APT to modify variables or to force I/O, and monitor the result in the field to test outputs from the controller.

Manual tests are an important means of finding errors in your program and in wiring, but they can be tedious and time-consuming since they are not automated.

Repeatable Logic Testing

You can write software test routines to check the application program. Since software routines can be stored as files, you can run them over and over very quickly and simply note the results.

APT includes MAITT (Main Application Integration Test Tool), a utility program that simplifies the task of repeatable logic testing. You can design the test routines to generate reports that are stored or printed. With MAITT, it is very easy to test the control system response to variable inputs. When you develop new code, you can easily test the existing code to verify that it still executes correctly.

While software routines can simplify your program tests, it is not likely that you would replace basic logic testing with software routines. It would be more appropriate to use both types of tests.

Dynamic Simulation

A good simulation is an excellent tool for discovering the problems that tend to remain hidden during program development. When you have developed a good, working, dynamic simulation, you can concentrate on developing the program code without being distracted by the actual execution of testing procedures. You can watch the code as it runs, and note problems as they occur. This is preferable to the manual testing described above.

There are two approaches to designing a simulation procedure for testing your process control program.

Internal simulations consist of test algorithms that are executed within the controller. This method can be quite an effective means of testing your program. However, your test program competes with the process control program for resources within the controller. For examples of internal simulations, refer to the example APT programs that are provided on the APT software CD.

External simulations consist of test algorithms that are executed in a separate computer that communicates with the controller. You can simulate virtually any mechanical or process control scenario and send the inputs to the controller, just as if they were actual field inputs. Since the external simulation does not reside within the controller, your test program does not compete with the process control program for resources within the controller.

A simulation requires considerable effort. However, you need to consider the cost of developing a good simulation versus the cost of not having one. Section 5.2 describes a commercially-available, dynamic-simulation programming language that you can use to write an external simulation.

5.2 APT and the TUTSIM Dynamic Simulation Package (Series 505)

APT includes two utility programs that enable you to use TUTSIM, a commercially-available dynamic-simulation programming language. TUTSIM is a high-level language that simulates the functions of an analog computer on a personal computer. This language consists of pre-defined blocks that enable you to use simple math, integral calculus, Laplace functions, thermodynamic equations, logic functions, etc., to simulate field inputs to the controller.

One block (SYC) can be used to synchronize the TUTSIM simulation with the real-time clock of the personal computer. Another block (USR) allows you to incorporate C language code into the TUTSIM environment. The two APT utility programs (**usrblk.exe** and **usrapt.exe** in the **\apt** subdirectory) together with the TUTSIM USR block allow the TUTSIM simulation program to read and write controller addresses.

The following pages explain how to use these APT utility programs with TUTSIM for the purpose of testing your APT application program. Additional information about TUTSIM and the software package itself can be obtained from TUTSIM Products at this address:

ACTUALity Corporation
TUTSIM Software
US Mail: P. O. Box 640
Morgan Hill CA 95037

E-mail: tutsimpa@aol.com
Phone 408–778–7773
FAX 408–778–8277

NOTE: Before you read the information that follows, you need to become familiar with the TUTSIM programming language.

Availability

The APT utilities that were written for the TUTSIM package are only for Series 505 controllers.

APT/TUTSIM Block

The APT utility, **usrblk.exe**, operates in conjunction with the TUTSIM USR block to create a customized APT block for communication with a Series 505 controller. **usrblk.exe** must be located in the same directory on your computer as the TUTSIM files. The graphical representation of the APT/TUTSIM block is shown in Figure 5-1.

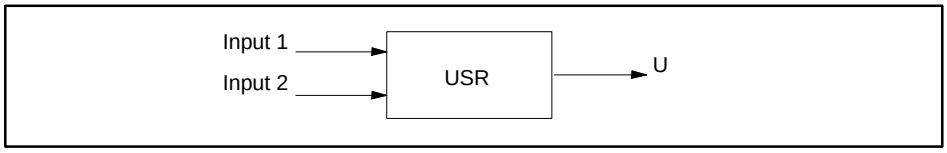

Figure 5-1 APT/TUTSIM USR Block

Parameters. The APT/TUTSIM USR block has three parameters.

- Parameter 1 indicates type of communication.
  0 = read from the controller.
  1 = write to the controller.
  2 = forced write to controller.

- Parameter 2 indicates the communication path number used in the TUTSIM.USR file (described on page 5-6).
  0 = the default APT environment communication.

- Parameter 3 indicates the initial value to be used in the block.

Inputs. The APT/TUTSIM USR block has two inputs.

- Input 1 enables/disables the block.
  0 = no read/writes are done.
  1 = a read/write to controller is done on a 0 to 1 transition.
  2 = a read/write to the controller occurs on every TUTSIM iteration.

- Input 2 contains a value for a write operation.

TUTSIM.USR File

The APT/TUTSIM USR block has an associated file, called **tutsim.usr**, that defines communication information and the Series 505 controller addresses. The APT utility program, **usrapt.exe**, preprocesses the **tutsim.usr** file and updates addresses from an APT program. **tutsim.usr** must be located in the same directory on your computer as the TUTSIM files. The APT program must be on the same drive as the **tutsim.usr** file when you run **usrapt.exe**, unless you use the APT_LOCAL DOS environment variable to set the path for a different drive.

The format of the **tutsim.usr** file is shown in Figure 5-2.

```
COMM <comm path #> <comm name> <comm port> <secondary>
COMM <comm path #> <comm name> <comm port> <secondary>
....
PROGRAM <APT program name>
UNIT <APT unit name>

BLOCK <tutsim block number> [%<address>] [<APT symbol name>]
BLOCK <tutsim block number> [%<address>] [<APT symbol name>]
BLOCK <tutsim block number> [%<address>] [<APT symbol name>]
...
UNIT <APT unit name>
BLOCK <tutsim block number> [%<address>] [<APT symbol name>]
```

Figure 5-2 TUTSIM.USR File Format

COMM command. The COMM command allows TUTSIM to communicate with multiple controllers, each with different communication requirements. All four parameters for COMM are required, even if they do not apply.

- Comm path # — integer number less than 32768 that identifies the communication path. Must be same value entered for the USR block parameter 2.

- Comm name — method for communicating with the controller.
  DIRECT = direct cable connection.
  HOST = UNILINK Host Adapter.
  CVU = CVU TIWAY Adapter or the 386/ATM Coprocessor.

- Comm port — communication port number.
  For Comm name = DIRECT or HOST, enter 1 for COM1, 2 for COM2, etc.
  For Comm name = CVU, enter any integer.

- Secondary — Secondary address.
  For Comm name = DIRECT or HOST, enter any integer.
  For Comm name = CVU, enter the TIWAY address.

PROGRAM and UNIT commands. The PROGRAM and UNIT commands identify the APT compiled program and unit. These commands direct the BLOCK command where to search to resolve the symbol. Consider these commands as toggles to be placed as needed before block commands. The UNIT command without a name searches Program Content level symbols.

BLOCK command. The BLOCK command defines the controller address for any USR block. You can define up 100 USR blocks. Any BLOCK defined in the file without a corresponding USR block is ignored during run time. The parameters for BLOCK are defined below.

- Block number — TUTSIM block number.
- Address — Controller address. If not defined, the utility **aptusr.exe** can determine the address. **aptusr.exe** can also replace the address with a revised address.
- APT symbol — APT symbol name for the block. If the symbol name is not defined, TUTSIM uses the absolute address. The utility **aptusr.exe** can update the address from the latest APT compile. Use the PROGRAM and UNIT commands when necessary to change the scoping of the symbol.

Figure 5-3 shows a sample **tutsim.usr** file. In this example, TUTSIM communicates through serial port COM1 of the personal computer. The APT compiled program is called **TEST01**, with units called BLENDER and PACKAGE. The example shows that the **usrapt.exe** utility was executed when only the BLENDER blocks were present. The next execution of **usrapt.exe** will update the BLENDER block addresses and insert the PACKAGE block addresses.

```
COMM 1 DIRECT 1 1
PROGRAM TEST01
UNIT BLENDER
BLOCK 10 %C40 BL_HOT_BVLV.OPND
BLOCK 11 %C50 BL_CLD_BVLV.OPND
BLOCK 12 %V1. BL_TC.SP
BLOCK 13 %WX9 BL_TEMP
UNIT PACKAGE
BLOCK 20 PK_PRD_DVLV.OPND
BLOCK 21 PK_LEVEL
```

Figure 5-3 Example tutsim.usr File

Example TUTSIM Program for Series 505

Figure 5-4 shows the listing for a simple TUTSIM program and an associated **tutsim.usr** file. From the **tutsim.usr** file, you can see that block 10 points to the Series 505 controller address C1 and block 11 points to address V1. The program reads C1 every 0.2 seconds and V1 every 0.4 seconds since the magnitude of USR input 1 is 0 or 1.

```
PROFESSIONAL VERSION OF TUTSIM

Model File:  test1.SIM
Date:       2 /     15 /     1992
Time:      11 :      56
Timing:      0.1000000   ,DELTA   ;   10.0000      ,RANGE
PlotBlocks and Scales
Format:
             BlockNo,        Plot-MINimum,       Plot-MAXimum;     Comment

Horz:          0,              0.0000     ,        10.0000       ;  Time
  Y1:         10,              0.0000     ,        1.0000        ;  READ FROM PLC AT CLK BLK 1 SAMP
  Y2:         11,              0.0000     ,        32.767E+3     ;  READ FROM PLC AT CLK BLK 2 SAMP
  Y3:           ,                        ,                      ;
  Y4:       9999,              0.0000     ,        1.0000        ;  REAL TIME SYNC PERFORMANCE

  0.2000000                    1 CLK                             ;  SAMPLE RATE CLOCK
  0.4000000                    2 CLK                             ;  SAMPLE RATE CLOCK
  0.0000                       10 USR           1                ;  READ FROM PLC AT CLK BLK 1 SAMP
  1.0000
  0.0000
  0.0000                       11 USR           2                ;  READ FROM PLC AT CLK BLK 2 SAMP
  1.0000
  0.0000
                               999 SYC                           ;  REAL TIME SYNC PERFORMANCE
```

TUTSIM Program

```
COMM 1     DIRECT 1
2
BLOCK 10   %C1
BLOCK 11   %V1
```

TUTSIM.USR File

Figure 5-4 Example TUTSIM Program and TUTSIM.USR File

Block Diagram Examples

Useful example algorithms are shown below in block-diagram format.

Figure 5-5 is an example of a program that simulates mass balance control for a tank. The simulation varies the analog input level based on valve positions in the feed and exit streams. Each valve has an associated gain to convert the boolean value to a scaled flow. An increase in the gain fills or empties the tank faster. The LMI integrator block clamps the tank at empty, full, or a range between. The GAI between the LMI and AI USR block converts a scale level to an appropriate AI range, 0–32000. A 20% offset analog input can be simulated by adding a SUM block with 6400 as an input.

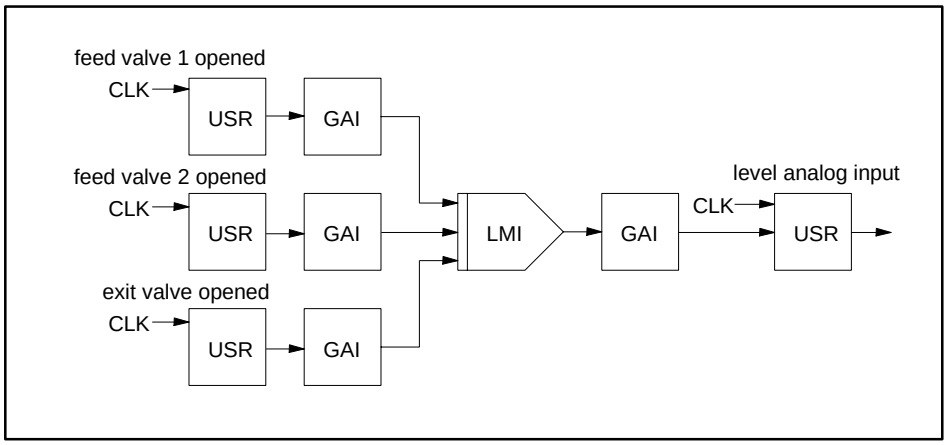

Figure 5-5 Example TUTSIM Algorithm for Mass Balance

Figure 5-6 illustrates how to simulate a pressure or temperature response to a PID loop. A first order lag (FIO) is placed between the output or setpoint and the process variable of the Series 505 controller PID loop.

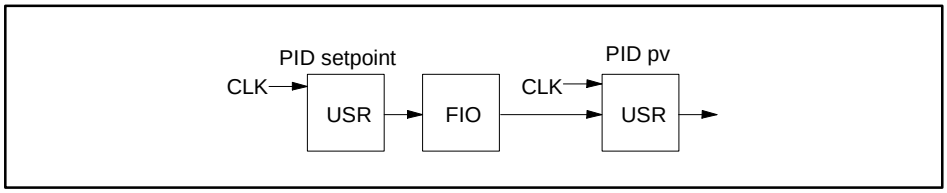

Figure 5-6 Example TUTSIM Algorithm for a PID Loop

Chapter 6

Redundant Configuration for S5

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6.1 Configuring an S5–155H Redundant System for APT

Overview

The S5 redundant controller system, 155H, is composed of two separate controller racks, each one containing one 948R CPU. The code for controlling the process can be programmed in APT. However, in order to run an APT program on an S5 redundant system, you must first configure the Operating System parameters using the COM 155H software package, which is purchased separately. APT does not configure the Operating System parameters for you.

This chapter explains how to recover the data you need from APT, and what parameters to enter in COM 155H. This document is not a tutorial; you must already be familiar with the information about COM 155H that is provided in the *S5-155H Programmable Controller (CPU948R) Manual*.

Options for Setting Up Your Redundant Configuration

When you are initially configuring your redundant system, there are two sequences you can follow, based on whether you wish to set up a new process, or modify an existing process.

When you set up a new process, you can reduce development time by writing and testing as much of your code as possible on a stand-alone 948R. You save the time that would be required to reconfigure with COM 155H after each program download. Follow this sequence.

1. Define your 948R CPU in the APT Compiler Control File by selecting CPU948.
2. Write your APT program and ensure that all code and I/O operates correctly for a stand-alone 948R.
3. Configure your operating system parameters in COM 155H. COM 155H writes to DX1 in the controller.
4. Bring your second controller online as the standby.

If you are expanding or changing an existing process, follow this sequence.

1. Define your 948R CPU in the APT Compiler Control File by selecting CPU948.
2. Configure your operating system parameters in COM 155H. You must configure the I/O at this point; however, you can incorporate your DB/DXs later, if you wish.
3. Bring your second controller online as the standby.
4. Make changes in APT and use incremental download to put the changes in the active controller.

⚠ CAUTION

If you select the "Clear P/C before download" option when you download your program, the operating system parameters that you selected using COM 155H are removed from the controller.

If the operating system parameters are removed from the controller, your redundant system does not function.

You must use COM 155H to transfer DX1 if you clear the operating system parameters from your controller by selecting the "Clear P/C before download" option.

Generating an APT Address Report and Configuring COM 155H

In order to set up a redundant system that is compatible with APT, you need to obtain certain data from an APT address report first. Furthermore, when you perform your operating system configuration, using COM 155H, you need to provide certain parameters, as specified in this chapter, that make your system compatible with APT.

The APT address report lists all of the controller memory that you are using; however, you only need to know which DB/DXs are used in the APT program.

Once you have generated an APT address report by the process that is described in Section 6.2, you are ready to invoke COM 155H. The COM 155H utility allows you to configure the four types of data listed below.

- Operating system parameters (SYSTEM)
  See Section 6.3.
- Data block transfer lists (TRAFDAT)
  See Section 6.4.
- Expansion units (I/O 314)
  See Section 6.5.
- I/O point configuration (IOCONF)
  See Section 6.6.

6.2 Generating an APT Address Report

Before you invoke COM 155H, you must generate an address report from APT in order to see which DBs and DXs APT is using. This section explains how to generate an APT address report. If you want more information about object files or the **P/C address to APT symbol name** option, see the section entitled “Downloading Program to Controller,” in the “Compiling an APT Program” chapter of the *SIMATIC APT User Manual*.

To access the object reports in the APT hierarchy, you must have a successfully compiled program. Generate a simple one, if necessary. Then go to the Program Content Directory and place your cursor on the following item:

OBJECT [ ] Successfully compiled program

Follow these steps.

1. Press R, or use the **OPTs** icon to select **Report**. The dialog window appears as shown in Figure 6-1.
2. Place an **X** between the brackets following the **P/C address to APT symbol name** option, to either save or print the report.
3. After selecting your report, move the cursor to **OKAY** and then press Enter.
4. Return to the APT hierarchy and read or print the report in Saved Reports.

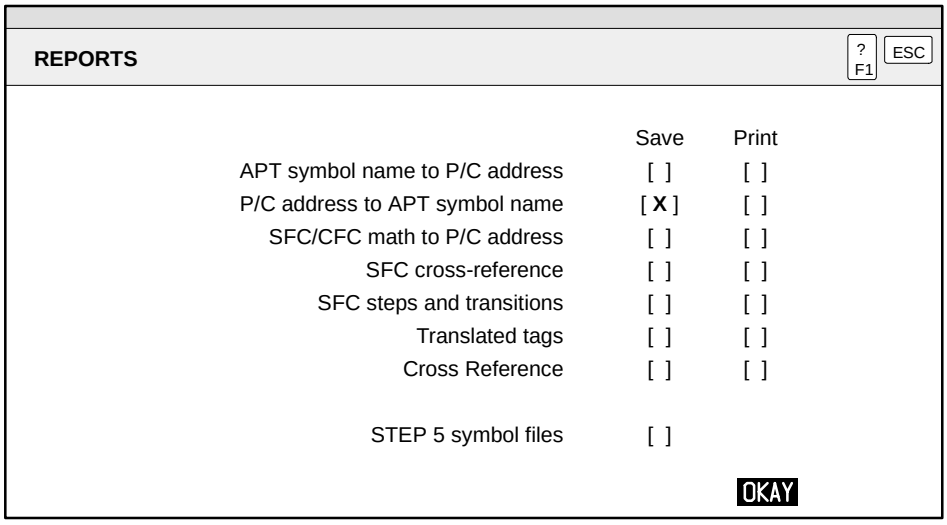

Figure 6-1 Creating an Address Report

Figure 6-2 shows a sample address report. Both data words and I/O are shown in the address report.

20/Apr/1995 07:01:14 PAGE 1
PLC ADDRESS TO APT SYMBOL NAME
PROGRAM NAME: BLD1A

Address	Symbol Name	Type	Scope
DB5:D0.0	A_STRT1	BOOLEAN	U2
DB5:D0.1	B_STRT1	BOOLEAN	U2
DB5:DW10	TOTAL_A	INTEGER	U1
DB5:DD30	A_BIAS	REAL	U1
DB5:DW100	ACCUM1	INTEGER	U1
DB6:DW0	FLOW_1	INTEGER	U2
DB6:DW1	FLOW_2	INTEGER	U2
DB7:DW2	FLOW_C	INTEGER	U2
DB7:DW3	EXCEP_CNT	INTEGER	U3
DB7:DD40	A_RATE	REAL	U3
DX5:DW0	TOTALIZ	INTEGER	U1
F10.1	STOP_ALL	BOOLEAN	$GLOBTBL
FW20	C_TEMP1	INTEGER	U1
FW32	C_TEMP2	INTEGER	U2
FW100	C_TEMP43	INTEGER	U6
I0.0	VLV_1_OLS	DIS IN	U1
I0.1	VLV_1_CLS	DIS IN	U1
I0.2	VLV_2_OLS	DIS IN	U2
I0.3	VLV_2_CLS	DIS IN	U2
I0.5	INTRLK1	DIS IN	U1
PW128	REAC1_TEMP	WORD IN/OUT	U3
PW130	REAC1_VOL	WORD IN/OUT	U3
PW132	REAC1_PRES	WORD IN/OUT	U3
PW144	TOTALIZE_1	WORD IN/OUT	$GLOBTBL
PW146	THERM1	WORD IN/OUT	$GLOBTBL
Q4.0	VLV1_OPEN	DIS OUT	U1
Q4.1	VLV1_CLOSE	DIS OUT	U1
Q4.2	VLV2_OPEN	DIS OUT	U2
Q4.3	VLV2_CLOSE	DIS OUT	U2
Q4.4	SHUT1	DIS OUT	U3

Figure 6-2 Analysis of DBs/DXs for COM 155H

Once you have a hard copy of the address report, you are ready to invoke COM 155H and define your operating system parameters.

6.3 Configuring Operating System Parameters from COM 155H

Operating System (SYSTEM) Parameters

To configure your SYSTEM parameters, you must first invoke COM 155H from STEP 5. Once you are in COM 155H, go to the Initialize Operating System screen. The operating system defaults that are used to program DX1 are shown in Figure 6-3.

Initialize Operating System — COM 155H / PEC16

Initializing the H operating system

No. of test slices (n*2ms)	(1...20):	1
H error DB number	(2...255):	3
RAM DB for variable data	(2...255):	4
H system flag word	(0...254):	0
Time stamp / F doubleword	(SEC/0..252):	SEC
Standard discrepancy time	(0.02s...320.00s):	0.05S
Readback delay	(0.02s...1.00s):	0.02S
IR DI byte available	(Y/N):	N

Behavior following RAM/PIQ comparison error: 0

0: Error search mode assume master value
1: Standby stop assume master value
2: Error search mode delete odd bits (PIQ)
3: Standby stop delete odd bits (PIQ)
4: Collective stop

F1	F2	F3	F4	F5	F6	F7	F8
							BACK

Figure 6-3 Initialize Operating System Screen

APT anticipates the default values from the Initialize Operating System screen shown in Figure 6-4. All the other input fields on the Initialize Operating System screen can be configured as required for your application. If you have already programmed DX1, check your SYSTEM parameters to make sure that the values you loaded conform to the items listed below, and modify the parameters if necessary.

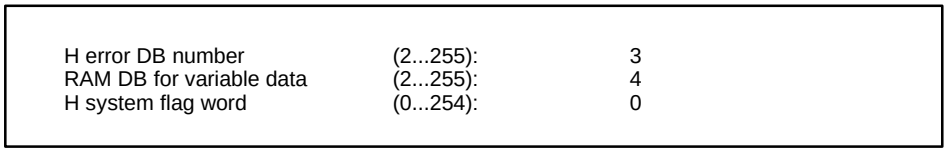

Figure 6-4 Values Required by APT

6.4 Configuring Data Block Transfer Lists from COM 155H

Transfer Data for Activating Standby (TRAFDAT)

After you have configured your operating system parameters, you can use TRAFDAT to specify your DBs and DXs for redundant control. For COM 155H, data blocks are organized according to the following four categories.

- Cyclic DBs
- Cyclic DXs
- Interrupt DBs
- Interrupt DXs

The address report that you generated in APT (described in Section 6.2) contains a list of all DBs and DXs in ascending order. Most DBs and DXs used within APT fall in the cyclic category, because they are used by code that is called by OB1. The only DB/DX used by APT that falls in the interrupt category is $RBED100. You must determine the actual DB or DX used for $RBED100 from the address report.

DB/DXs that are used by an interrupt OB that you have programmed (OB2 through OB18) fall into the interrupt category. You are responsible for keeping track of all the DBs and DXs that are used in your interrupt OBs, and for determining whether a given DB/DX belongs to a cyclic OB or else to an interrupt OB. If a DB or DX is shared by both interrupt and cyclic, enter it only in the interrupt area.

NOTE: All DBs and DXs in the address report must be entered in TRAFDAT.

Figure 6-5 shows how to analyze an APT address report and how to determine whether a DB/DX belongs in the cyclic table or the interrupt table. Even though the address report enumerates all the data words within a given data block, you need to make only one entry for the entire data block to indicate whether it is interrupt or cyclic.

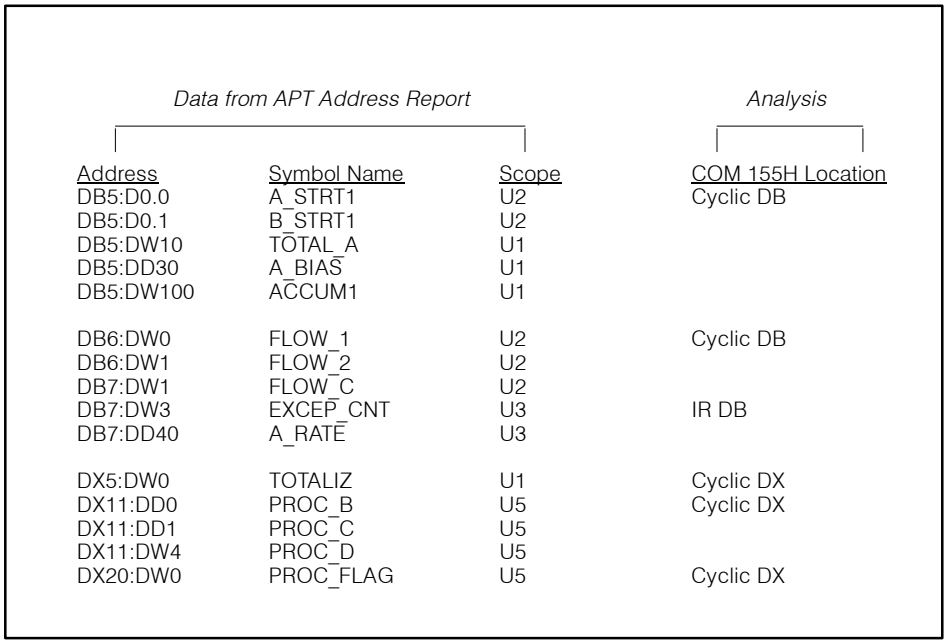

Figure 6-5 Analysis of DBs/DXs for COM 155H

Figure 6-5 shows that DB5 and DB6 need to be entered into the Cyclic DB table and that DX5, DX11 and DX20 need to be entered into the Cyclic DX table. DB7 is used to program an interrupt OB, and is also used in the cyclic program; since it is shared by both interrupt and cyclic, it must be placed in the Interrupt DB section.

See the section entitled “Initializing Activation of the Standby” in the *S5-155H Programmable Controller (CPU948R) Manual* for information on how to use TRAFDAT to enter these DBs and DXs.

6.5 Configuring Expansion Units from COM 155H

Configuring Expansion Units (I/O 314)

APT does not contain any information about which expansion units are connected to the controller. You need to enter your expansion units in COM 155H by using I/O 314. To configure I/O 314, see the section entitled "Initializing the I/O Areas" in the *S5-155H Programmable Controller (CPU948R) Manual* for more information.

6.6 Configuring I/O from COM 155H

IOCONF

The 155H redundant system does not operate properly until you configure every I/O point and channel, using IOCONF from within COM 155H.

> **⚠ CAUTION**
>
> **You must specify all I/O points and channels in a redundant system.**
>
> **If you do not specify all of your I/O points and channels in COM 155H when you are setting up your redundant system, the standby unit does not come online.**
>
> **Ensure that you have specified your I/O in its entirety, using IOCONF.**

The address report that you generated from APT (see Section 6.2) contains information on each I/O point used within APT. For every I/O location, APT stores the address and APT type (word or discrete, input or output). APT does not attempt to keep up with the I/O mode (switch, redundant, etc.).

You must define all points that are on the I/O cards, whether they are used in APT or not, when you use IOCONF in COM 155H. You also need to specify the I/O mode, based upon your hardware configuration. Table 6-1 shows the correspondence between APT I/O types and S5 I/O types.

Table 6-1 How APT I/O Types Map to S5

APT I/O Type from Address Report	I/O Type from COM 155H IOCONF
DIS IN	DI
DIS OUT	DQ
WORD IN	AI
WORD OUT	AQ

CPs and IPs are not configured within APT. If your system is using them, it is your responsibility to assure they are configured correctly.

See the section entitled “Configuring the I/O” in the *S5-155H Programmable Controller (CPU948R) Manual* for more information about IOCONF.

If your controller is to be connected to OSx, see the section entitled “S5-155H Configuration” in the *SIMATIC PCS 7 OSx Interface to S5 Controllers User Manual* for important configuration information.

Chapter 7

APT and the OSx Operator Interface

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7.1 Using APT to Configure an OSx Database

In a process control system, a controller and an operator interface interact to control and monitor the process. The controller has the actual physical control over the process, while the operator interface monitors the process. You can use APT to program the controller and to configure the objects and variables that are sent to the operator interface. The controller addresses for objects that are monitored by the operator interface must remain unchanged in the controller program if the operator interface is to access data during run time. The APT **Mark Tags** utility enables you to fix the locations of variables in memory.

After objects are marked for an OSx operator interface, the APT Compile, **Translate File Build**, places the variable name, descriptor, controller address, and other information into a file called **install.tag**. The data in this file can be used to automatically update the OSx database. For a non-OSx operator interface, you must enter this information into its database manually.

This procedure is designed for an OSx system, but you can use it for any operator interface. Currently, there are four releases of PCS/OSx available: TISTAR 1.x, TISTAR 2.x, and PCS 3.x and OSx 4.x. TISTAR 1.x and TISTAR 2.x can read similar **install.tag** files, although TISTAR 1.x cannot translate APT units. The format for the **install.tag** file (Figure 7-1) used with PCS 3.x and OSx 4.x is different: it is a comma-delimited file that can be imported and exported to and from spreadsheet programs for editing. The **install.tag** file is located in the **\apt\program*program_name*\prr** subdirectory, where ***program_name*** is the name of your APT program. Appendix A of this manual describes the **install.tag** files.

APT supports all types of memory on the various Series 505 and S5 controllers. However, VMM and VMS memory, used in the 575 controller, cannot be translated to OSx; and FW, FD, S, SW, SD and RSW memory, used in an S5 controller, cannot be translated to OSx. For an S5 controller, D-memory cannot be read from OSx directly; however, APT does translate D-memory, by packing bits into a word (DW) that can be translated and read by OSx.

TISTAR 1.x and 2.x are limited to translating only 64K bytes of V-memory and K-memory for Series 505 controllers. APT displays a warning when more than 64K bytes have been allocated for these memory types for translation.

Figure 7-1 shows the **install.tag** file for a 575, which is a Series 505 controller. For an S5 controller, the Memory column displays S5 memory types; for example, DB3:DW1 for data word 1 in data block 3.

Record	Control-Node	Tag-Type	Tag	Description	Process-Group	Manual-Set	Parent	Attribute	Memory	Locations	Upload	Twenty-%	Autolog	Init-Value
T	575	LOOP	TLOOP	temp loop	0x1	N								
A								CHANGE						1
A								SP	V.1	1	N		N	0
A								STATUS	LSTATUS1	1	N		N	0
A								MODE	LMode1	1	N		N	0
A								L_RANGE	LPVL1	1	Y		N	0
A								H_RANGE	LPVH1	1	Y		N	400
A								PV	LPV1	1	N		N	0
A								ROC_ALM	V.27	1	Y		N	1
A								L_DEV	V.25	1	Y		N	5
A								H_DEV	V.23	1	Y		N	10
A								LL_ALM	V.21	1	Y		N	1
A								L_ALM	V.19	1	Y		N	10
A								H_ALM	V.17	1	Y		N	350
A								HH_ALM	V.15	1	Y		N	380
A								RATE	V.13	1	Y		N	0
A								RESET	V.11	1	Y		N	0.1
A								GAIN	V.9	1	Y		N	10
A								OUT	V.3	1	N		N	0
T	575	DO	TLOOP.NRDY		0x1	N								
A								COMMAND	C22	1	N		N	0
A								STATUS	C22	1	N		N	0
T	575	IVAR	RT1.NUM_RUN	number of batches	0xffffffff	N								
A								H_RANGE						32767
A								L_RANGE						0
A								VALUE	V5	1	N		N	5
A								STATUS	V5	1	N		N	5

Figure 7-1 Portion of an Example INSTALL.TAG File for PCS 3.x

The following procedure summarizes the three steps required to place APT object data into the OSx-compatible database. Steps 1 and 2 ensure that controller addresses remain constant for the operator interface.

1. Mark objects for translation (Section 7.2). In this step you select objects (tags) that are to be used by the operator interface and that must have unchanging controller addresses.

2. Compile the program (Section 7.3). This step builds the executable code used by the controller and creates the **install.tag** file that contains object data. When you compile the program, controller addresses are fixed for each object that you marked in Step 1.

3. Translate the tags (Section 7.4). Translation places the tag data, which was created by the compile step, into a formatted OSx database.

You must follow each step for any operator interface. For OSx, all three steps can be done by selecting the appropriate option while you are executing APT. For any other operator interface, you can do Step 1 and Step 2 while executing APT. The third step is a manual procedure in which you must prepare the database to be used by the operator interface. Refer to Appendix A for recommendations about how to proceed.

7.2 Marking Tags for Translation

Use the **Mark Tags** option to select those objects that are used by the operator interface and that must have fixed controller addresses. If your application requires it, you can also unmark an object after you you have marked it for translation. The *SIMATIC APT User Manual* describes the steps involved in marking and unmarking objects for translation. You can use the APT **Mark Tags** option for any type of operator interface.

Tag translation creates the OSx tags from APT objects. Table 7-1 shows the OSx tag types and their corresponding APT objects. Several APT objects are used specifically as configuration tools for OSx. Table 7-2 lists these objects. An AREA tag is an APT recipe area. A UNIT or OSx parent tag is the unit in APT to which the APT object belongs. The non-networked tag is an object in APT for which the controller address is selected as none. This means that no controller address was assigned and that it cannot be downloaded to the controller. The non-networked tag is for OSx use only; you cannot use it anywhere else in the APT program.

Table 7-1 OSx Tag Types

APT Object	OSx Tag	APT Object	OSx Tag
Recipe Area Name	AREA	APT Valve Device [1]	VLV1
Real Variable [1], Analog Input [2]	CALC		VLV2
Integer Variable [1]	IVAR	APT Motor Device [1]	MTR1
Digital Output, Boolean	DO		MTR2
Digital Input or APT Flag	DI	APT Reversible Motor Device [1]	RMTR
PID Loop	LOOP	APT Unit	UNIT
Analog Alarm or Analog Input[2]	AI	DO10	DO10
Analog Output	AO	DI10	DI10
Timer	TMR	Text	TEXT
Counter	CTR		

1 Used by many objects in APT. For a detailed list, refer to Appendix C, "OSx and TISTAR Tag Translation".
2 Analog Input can be translated as both a CALC and as an AI tag type. Analog Inputs also include Thermocouple and RTD inputs.

Table 7-2 Objects Used as Special Configuration Tools for OSx

Function	APT Object	APT Extension	OSx Object
Declarations	Text		TEXT tag
	Text array		TEXT tag
	DI10		DI10 tag
	DO10		DO10 tag
Unique status		*variable_name*.**STATUS**[1]	
When None is specified as the controller address			Non-networked tag
Recipes [2]	Recipe		Recipe
		recipe_name.**INUSE**	In_use bit
		recipe_name.**DSTBL**	Stable bit
		recipe_name.**DRDY**	DataReady bit
Scale Recipe			Scale High attribute
			Scale Low attribute
Scale Factor		*recipe_name*.**SCALE** [3]	Scale_Factor attribute
Hold Recipe		*recipe_name*.**HOLDREQ** [3]	Hold_req attribute
Controller Request		*recipe_name*.**RECREQ** [3]	PLC_rec_req attribute
Batch Operations [4]	Unit		
Batch Request		*unit_name*.**BCH_REQ**	BCH_REQ
Batch Request Response		*unit_name*.**BCH_REQ_RESP**	BCH_REQ_RESP
Batch Request Info		*unit_name*.**BCH_REQ_INFO**	BCH_REQ_INFO

1. The status attribute is available for integers, scaled integers, booleans, and text declarations. To get the status attribute for a real number, you must choose Create Unique Status on the Real Declaration Form.
2. Refer to the Recipes chapter (Chapter 9) in the *SIMATIC APT Programming Reference (Tables) Manual* for how to use recipes with OSx.
3. These extensions are assigned when you choose Create Unique Scale Factor, Create Unique Hold Request, or Create Unique Controller Request in the Recipe Usage Table.
4. Refer to Appendix C for how to use the batch control with OSx.

APT provides four editors for marking objects for translation: the Tag Translate editor, the Tag Translate sub-editor, the Tag Attribute sub-editor, and the Process Group sub-editor. The Tag Translate editor allows you to mark simple APT objects, such as declarations, for translation to OSx. The Tag Translate sub-editor also allows you to mark complex objects, such as CFBs, recipes, or declarations with more than one associated extension, for translation. After marking a complex object, you then edit the object to mark individual extensions of the object.

After marking an object, the Tag Attribute sub-editor allows you to specify scan status, upload, or 20% offset for the object. You can specify autolog only for PCS 3.x and OSx 4.x; download is only available for TISTAR 1.x and 2.x.

After marking an object, you can use the Process Group sub-editor to specify the OSx process group to which a tag belongs. Consult the *SIMATIC PCS 7 OSx Process Configuration Manual* for more information about assigning tags to process groups.

You cannot delete objects that you mark for OSx without first unmarking the objects. You also cannot change the contents of a field that sets address locations without unmarking the object containing the field. For declarations, these fields include the type of object and whether it is constant, the number in an array, the controller address, or the unique status of the object. All these fields affect the variable's address in the controller. However, you can change initial values, high/low ranges, and engineering units without unmarking the object.

For recipes, you can only change component values without unmarking recipe objects. To change any other item, you must first unmark the recipe.

Marking Tags for Translation (continued)

Recommendations for Marking Objects

Keep these points in mind when you mark objects for translation:

- Take Small Steps. It is recommended you test objects in an incremental fashion. That is, develop a portion of your program, and then test the objects. Then, develop the next portion of the program and test objects for that portion. When you are certain that your code is correct, then mark objects for translation.
- Mark the Device, Not the Elements. When you want to mark a device, you do not need to mark all the individual elements, e.g., commands, feedbacks, etc.
- Mark Loops. When you mark a PID loop block, most loop variables are included for translation. It is unnecessary to mark analog inputs/outputs for the loop separately in the I/O Table.

When you mark analog inputs not associated with a PID loop or analog alarm, remember these points:

A scaled real variable maps to the OSx CALC tag type with no alarm capabilities.

An integer raw variable maps to the OSx AI tag type with alarm capabilities. APT does not fill in the alarm values. To enter these values, you must use the OSx tag configurator (TISTAR Releases 1.x and 2.x), or else edit the **install.tag** file as described in Chapter 5 of the *SIMATIC PCS 7 OSx Process Configuration Manual* (PCS 7 OSx 4.x).

NOTE: Do not overload installation. Limit the number of marked tags to 1,000 tags per program to speed up tag installation.

7.3 Compiling the Program

When you compile the program, APT builds the executable code used by the controller. APT fixes controller addresses for objects during the compile procedure. It is not essential to mark all objects before you compile a program, because you can append tag information to the file containing the tag data. However, you should decide which objects are required by the operator interface and mark them all before compiling. You can use the APT **Compile** option for any type of operator interface.

The first time you compile a program after marking objects, select these options in the Compiler Control File:

```
                Force compile?    [X]
            Build translate table? No      Append    Yes
Units to compile - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
                    Include all?  [X]  1 of 1 included
```

Recommendations for Compiling a Program

Keep these points in mind when you fill out the Compiler Control Form.

Force Compile After a successful compile, subsequent compiles may execute more quickly after you make minor code changes. This is because some sections may not be revalidated. Refer to the "Compiling an APT Program" chapter of the *SIMATIC APT User Manual* for a complete discussion about the program compile operation.

Build Translate Table When you do not want addresses for the marked objects to change after the initial program compile, do not select **Yes** for the **Build Translate Table** option during subsequent program compilations. If you need to recompile the program, select **No** for **Build Translate Table**. To include additional tag data, see the Adding Tags section, which follows.

If you select **Yes** for the **Build Translate Table** option when you compile a program, take note. If you have already compiled the program using the **Yes** option, addresses for objects, which were fixed by the earlier compilation in the file **install.tag**, will change. Refer to the "APT, OSx/TISTAR and TISOFT/STEP 5" chapter of the *SIMATIC APT User Manual* and to Appendix A of this *SIMATIC APT Applications Manual* for more information about the **Build Translate Table**, option and the **install.tag** file.

Mark Units The **Units to Compile Include All** option must remain selected if you do not want the addresses of previously marked objects to change.

Adding Tags You can add tags without affecting the addresses of previously marked objects. To do this, mark the objects and select **Append** for the **Build Translate Table** option when you recompile a program. The **Append** selection adds new object addresses to the file **append.tag**, which contains tag data for appended tags, without changing addresses of previously marked objects. If you need to recompile the program after appending tag data, select **No** in the **Build Translate Table** option, and no object addresses are changed. Refer to the "APT and OSx/TISTAR, and TISOFT/STEP 5" chapter of the *SIMATIC APT User Manual* and to Appendix A of this manual for more information about the **append.tag** file.

NOTE: If you make changes to your system, e.g., adding RCCs or changing controller models, addresses may change, even if you have selected the **Append** option. See the "Compiling an APT Program" chapter of the *SIMATIC APT User Manual* for more details.

Handling Complex Tags When you mark a complex object, such as a valve or motor, only a subset of the object extension addresses is fixed. A detailed list of these is given in Appendix B, "Extensions Fixed by the Compile."

Report by Exception

Some categories of information are reported by the controller automatically, without a demand scan from an OSx operations station. Examples include: alarms and alarm acknowledgements, the automatic logging of messages, action requests, BCL jobs, and recipe handshaking exchanges. This process is called Report By Exception (RBE) and is supported in PCS 3.x/OSx 4.0.0 and later.

The RBE process is a data management system used in OSx. The RBE capability exists in Release 3.x or greater firmware of the 545–1102, –1103 (545 Lite) and –1104, 555–1101, –1102, –1103, –1104, –1105, and –1106, and 575–2103, –2104, –2105, and –2106 controllers. The S5 controller programs require a function block package for the RBE process, which is included by selecting **RBE code included** on the Compiler Control File. Refer to the *SIMATIC PCS 7 OSx Interface to S5 Controllers Manual* for more information.

Reserving Memory for RBE (Series 505)

The Series 505 controllers have factory-allocated memory to store 20K bytes of RBE definitions. 20 Kbytes is the minimum memory allocation. Any entry less than 20 Kbytes results in the minimum amount being allocated. If the number of RBE tags in a given controller requires more than 20K, you can determine the total memory required for all tags and enter the amount in the APT Compiler Control file, or just allow the controller to use unconfigured user memory to hold additional RBE tag definitions. Unconfigured user memory is the memory above the amount APT has configured for the program. The memory configuration amounts are contained in the Compile Report.

The memory required for a given tag depends on the tag type (Table 7-3). For a typical OSx tag mix, the average memory requirement is 42 bytes per tag. This means that you can define approximately 490 tags in a given controller before the RBE tag definitions require unconfigured user memory. Depending on the memory requirements of the controller program, it is possible to define a larger number of tags. However, the amount of unconfigured controller user memory available for RBE definitions can change over time if you make changes in the controller program.

If insufficient controller memory is available for RBE, then OSx handles tags that could not be stored as RBE definitions in the controller as demand scan tags. The system scans these tags continually at the Event Scan Period. Refer to the “OSx System Architecture” chapter in the *SIMATIC PCS 7 OSx System Administration Manual* for more information about RBE and demand scan.

After compiling, you can view the compile report that contains OSx Tag Type Usage in Phase 7, Translate File Builds, or create a tag report from the object file reports. The tag report lists the OSx tag types and information about the attributes. The report is not as detailed as the **install.tag** file, but you can view it in APT. These reports give you the total number of tags for each tag type that you can use in your calculations for memory requirements.

Table 7-3 RBE Memory Requirements for Series 505 Controllers

Tag Type	Controller Memory Requirement (Bytes)	Tag Type	Controller Memory Requirement (Bytes)
ai	42	do	28
ao	42	do10	28
batch	42	ivar	36
calc	36	loop	54
ctr	42	area	42
device	48	text	48
di	28	tmr	42
di10	28	unit	48

7.4 Translating Tags

The last phase of setting up the connections to the operator interface involves tag translation. In this phase, tag data is moved into a formatted database that can be used by the operator interface.

For a non-OSx operator interface, this is a manual procedure. Refer to Section 3.9 for recommendations about how to proceed.

For OSx, tag translation is an automated procedure. You can choose from five procedures for translating tags into the OSx format. The procedures vary, depending upon your controller type and how your APT and OSx systems are configured. Refer to the *SIMATIC APT User Manual* for instructions in following one of these procedures.

- Tags translated on a OSx APT engineering node using the Industrial Ethernet network (Series 505 and S5)
- Tags translated on an APT workstation that is not in communication with OSx, using the **TRANSOFF** option (Series 505 and S5)
- Tags translated outside the APT environment, using the **TRANSOFF** option (Series 505 and S5)
- Tags translated on a TISTAR operating station (Series 505 only)
- Tags translated on a non-TISTAR operator station (Series 505 only)

Appendix A

Defining a Variable's Address

A.1 Determining a Variable's Address A-2
Reading Translated Tag Reports A-2
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Reading Symbol/ Address Reports A-3
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An Analysis of the INSTALL.TAG File Examples for PCS/OSx A-14

A.1 Determining a Variable's Address

To determine the address of a specific variable, you can:

- Read the report for translated tags.
- Use the Debug **Direct Address** function.
- Read the symbol/address reports.
- Use the APT DC utility.
- Read the **install.tag** file.

Reading Translated Tag Reports

You can have APT generate a report for translated tags. Place the cursor on the **Object** icon and select **Report**. Then, select the **Translated Tag** option. If you save the report, APT places it under the Saved Report Level of the hierarchy with the name **tag.rpt.**

The following information appears in **tag.rpt** for each marked object:

- APT and OSx tag names.
- Controller address.
- Selected OSx attributes and their status.

tag.rpt is located in this subdirectory:

\apt\program*program_name*\prr

where ***program_name*** is the name of your APT program.

Using Debug

You can determine the controller address for a variable while running the Debug utility. Press Alt D or use the **OPTs** icon to select **Direct Address.** APT prompts you to enter the unit and variable names and then reports the controller address.

Reading Symbol/ Address Reports

You can have APT generate a report on the compile operation. Place the cursor on the **Object** icon and select the **Report** function. You can choose from two types of report on variable addresses:

- APT symbol name to P/C address
- P/C address to APT symbol name

Select one of these two options. If you save the reports, APT places them under the Saved Report Level of the hierarchy with these names: **symbol.rpt** and **address.rpt**. You can examine a report within the APT environment, or have APT send the report to a printer. (These reports are usually quite long and you may not want to wait for them to print.)

You can also examine a report by using any text editor in the DOS environment. The file names are **symbol.rpt** and **address.rpt**, located under the following subdirectory: **\apt\program***program_name***\prr** where *program_name* is the name of your APT program.

Using the APT DC Utility

The DC utility performs all the functions that the APT **Report** option provides for an object, as well as resolving individual symbol addresses. The DC **Resolve Symbol** option is very useful for determining addresses when only a few locations are needed. When you want to work in the DOS environment, use the DC utility rather than using the Debug **Direct Address**. Follow the steps below.

1. At the DOS prompt for the drive containing the APT program, type **DC** and press Enter.
2. At the menu prompt, type **5 (Resolve Symbol)** and press Enter.
3. Type the program name and press Enter.
4. For a local variable, type the unit name and press Enter.
   For a global variable, just press Enter.
5. Type the APT symbol name and press Enter. Be sure you include the extension. The system displays the address assigned to the variable.
6. Type 0 to quit.

For example, consider the symbol **Tk1_a.opnd** with the controller address C88, in unit **Tank_1**, of a program called *BLENDER*. Use the DC utility, following the steps below.

1. At the DOS prompt, type **DC** and press Enter.
2. At the menu prompt, type **5** and press Enter.
3. Type **Blender** and press Enter.
4. Type **Tank_1** and press Enter.
5. Type **Tk1_a.opnd** and press Enter.

   (Series 505 Controllers)
   The system displays the message: **Resolved: C88.**

   (S5 Controllers)
   The system displays the message: **Resolved: DB10:D6.0.**

Reading the *INSTALL.TAG* File for TISTAR Release 1.x and 2.x (Series 505)

During a program-compile operation, APT stores tag information in an ASCII file, **install.tag**. Although tailored for the TISTAR database, the information can be used for any operator station package to determine the controller address of a variable.

The **install.tag** file is located under the **\apt\program***program_name* directory, where *program_name* is the name of your APT program. You can examine **install.tag** by using any ASCII text editor.

An example of an **install.tag** file for a Series 505 controller is shown in Table A-1. The **S** identifier informs TISTAR that the **install.tag** file contains six tags and that they are to be installed in the secondary called Blender.

The two tags BR.ADD_A and D_SETPT are real numbers. Each tag has several variables with initial values. The address for BR.ADD_A, assigned to the VALUE attribute as V.23, is both V23 and V24, since the variable is a real number. The address for D_SETPT, assigned as V.7, is both V7 and V8.

The tag called TK1_RESTART is a Boolean entity. The address for TK1_RESTART, assigned to the COMMAND and STATUS attributes, is C369.

The tag called BATCH_MODE is an integer. The address for BATCH_MODE, assigned to the STATUS and VALUE attributes, is V232.

The name of the loop is TK1_TC. The number immediately following the word LMode in the MODE attribute is the address of the loop in the controller: that is, Loop 1.

The information contained in **install.tag** has the organization described in Table A-1.

Table A-1 *INSTALL.TAG* File Example for TISTAR Release 1.x and 2.x

S	00000006 BLENDER
T	AREA BR
P	Blender recipe
T	CALC BR.ADD_A
P	Amount of ingredient A
R	BR
V	UNITS lbs
V	DEADBAND 0.1
V	H_RANGE 150.0
V	L_RANGE 0
C	ADD A
N	VALUE V. 23 1 1 0 0 2 85.0
T	CALC D_SETPT
P	Setpoint of ingredient D
V	DEADBAND 0.1
V	H_RANGE 10000
V	L_RANGE 0
N	VALUE V. 7 1 1 0 0 2 100
T	DO TK1_RESTART
P	Restart the process
N	COMMAND C 369 1 0 0 0 2 0
N	STATUS C 369 1 1 0 2 2 0
T	IVAR BATCH_MODE
P	MODE = auto, man, or jog
V	H_RANGE 1000
V	L_RANGE 0
N	STATUS V 232 1 0 0 2 2 0
N	VALUE V 232 1 1 0 0 2 0

Table A-1 *INSTALL.TAG* File Example for TISTAR Release 1.x and 2.x (continued)

T	LOOP TK1_TC
P	temperature control
V	DEADBAND 0.1
N	SP V. 13 1 1 0 0 2 40
N	STATUS LSTATUS 1 1 1 0 2 2 0
N	MODE LMODE 1 1 0 0 0 2 0
N	L_RANGE LPVL 1 1 2 1 0 2 40
N	H_RANGE LPVH 1 1 2 1 0 2 212
N	PV LPV 1 1 1 0 2 2 40
N	ROC_ALM V. 255 1 0 1 0 2 1
N	L_DEV V. 253 1 0 1 0 2 0.5
N	H_DEV V. 251 1 0 1 0 2 2.5
N	LL_ALM V. 249 1 0 1 0 2 50
N	L_ALM V. 247 1 0 1 0 2 60
N	H_ALM V. 245 1 0 1 0 2 180
N	HH_ALM V. 243 1 0 1 0 2 205
N	RATE V. 241 1 0 1 0 2 0
N	RESET V. 239 1 0 1 0 2 4
N	GAIN V. 237 1 0 1 0 2 10
N	OUT V. 15 1 1 0 0 2 0
E	

INSTALL.TAG File: (First Line) The first line of the file starts with a **S** identifier and contains the number of tags in the file and the name of the TISTAR secondary (Table A-1).

INSTALL.TAG File: (Second Line) The second line of the file starts with a **T** identifier and contains the tag type and name of the first tag (shown in Table A-1). This line determines the amount of information associated with each tag. Table A-2 lists the TISTAR tag types, which are determined by APT.

Table A-2 TISTAR Tag Types

Tag Type	Acronym	Tag Type	Acronym
Recipe area name	AREA	Timer	TMR
Real variable	CALC	Counter	CTR
Integer variable	IVAR	APT valve device	VLV1
Digital output	DO	APT valve device	VLV2
Digital input or APT flag	DI	APT motor device	MTR1
PID loop	LOOP	APT motor device	MTR2
Analog alarm or analog input	AI	APT reversible motor device	RMTR
Analog output	AO	Digital output array of 10	DO10
Text	TEXT	Digital input array of 10	DI10

INSTALL.TAG File: (Subsequent Lines) The next several lines start with different identifiers depending upon the tag type (**P**, **R**, **V**, **C**, or **N**) and contain attribute information for the first tag listed in the **install.tag** file (shown in Table A-1). The number of lines for each tag varies with the tag type. Table A-3 lists the attribute identifiers and a description of what is contained in each.

Table A-3 Tag Type Attribute Identifiers

Identifier	Field Contents
P	Description of tag
R	Name of TISTAR recipe area (if tag is part of recipe)
V	Attribute with an initial value only (may be zero, one, or more)
N	Attribute with an address, options, and an initial value (may be more than one)
C	Component name in recipe area (if the N attribute above is part of a recipe)

The **N** identifier precedes the TISTAR attributes that have a corresponding address in the controller. TISTAR attributes include STATUS, VALUE, COMMAND, SETPOINT, OVERRIDE, MODE_CMMD, L_RANGE, H_RANGE, MODE, PV, SP, OUT, ROC_ALM, L_DEV, H_DEV, etc. For each attribute, eight types of data are stored. The format for a line with an **N** identifier is shown in Figure A-1.

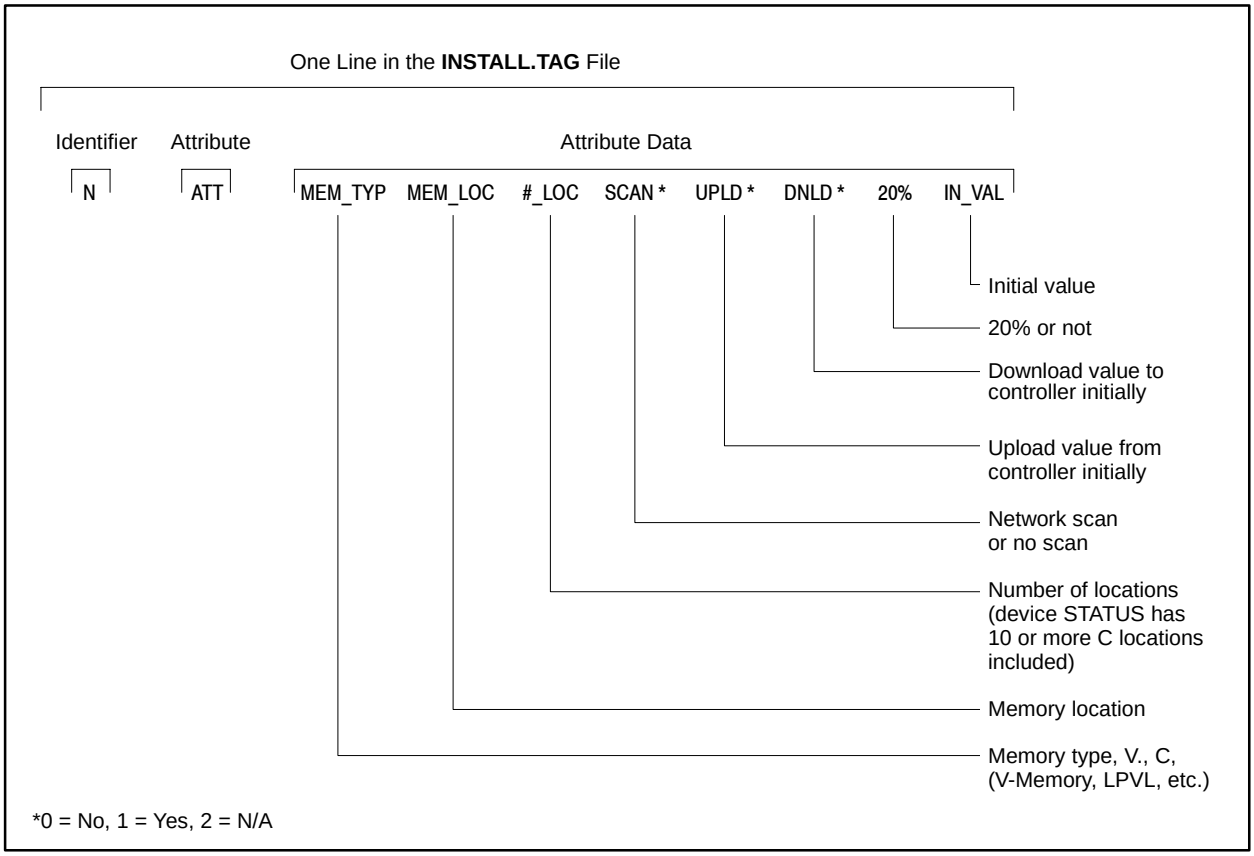

Figure A-1 Format for an N Line in the INSTALL.TAG File for TISTAR 1.x and 2.x

Following the first tag, information for the second tag is listed. The first line for the second tag contains a **T** identifier and contains the tag type and name of the second tag.

Following the attribute information for the second tag, information for subsequent tags is listed.

INSTALL.TAG File: (Last Line) The last line of the file starts with an **E** identifier (shown in Table A-1).

Reading the *INSTALL.TAG* File for PCS Rel. 3.x and OSx Rel. 4.x

During a program-compile operation, APT stores tag information in an ASCII file, **install.tag**. Although tailored for the PCS/OSx database, the information can be used for any operator station package to determine the controller address of a variable.

The **install.tag** file is located under the **\apt\program***program_name* directory, where *program_name* is the name of your APT program. You can examine **install.tag** by using an ASCII text editor, as shown in Figure A-2, or you can examine **install.tag** using a spreadsheet program, as shown in Figure A-3. The format for release 3.x is comma-delimited, to be easily used in a spreadsheet program. The information contained in **install.tag** has the organization described below.

The **install.tag** file for PCS 3.x and OSx 4.x is organized in sections as follows: Tags and Attributes, Recipes and Components, and then Process Groups. There is a field description line for each section: one for tags, one for recipes, and one for process groups, to identify the information in each column. The subsequent lines in the section describe the data.

```
Record,ControlNode,TagType,Tag,Description,ProcessGroup,ManualSet,Parent,Attribute,Memory,Locations,Upload,
Twenty%,Autolog,InitValue
T,575,LOOP,TLOOP,temperature loop,0x1,N
A,,,,,,,,CHANGE,,,,,1
A,,,,,,,,SP,V.1,1,N, ,N,0
A,,,,,,,,STATUS,LSTATUS1,1,N, ,N,0
A,,,,,,,,MODE,LMode1,1,N, ,N,0
A,,,,,,,,L_RANGE,LPVL1,1,Y, ,N,0
A,,,,,,,,H_RANGE,LPVH1,1,Y, ,N,400
A,,,,,,,,PV,LPV1,1,N, ,N,0
A,,,,,,,,ROC_ALM,V.27,1,Y, ,N,1
A,,,,,,,,L_DEV,V.25,1,Y, ,N,5
A,,,,,,,,H_DEV,V.23,1,Y, ,N,10
A,,,,,,,,LL_ALM,V.21,1,Y, ,N,1
A,,,,,,,,L_ALM,V.19,1,Y, ,N,10
A,,,,,,,,H_ALM,V.17,1,Y, ,N,350
A,,,,,,,,HH_ALM,V.15,1,Y, ,N,380
A,,,,,,,,RATE,V.13,1,Y, ,N,0
A,,,,,,,,RESET,V.11,1,Y, ,N,0.1
A,,,,,,,,GAIN,V.9,1,Y, ,N,10
A,,,,,,,,OUT,V.3,1,N, ,N,0
T,575,DO,TLOOP.NRDY,,0x1
A,,,,,,,,COMMAND,C22,1,N, ,N,0
A,,,,,,,,STATUS,C22,1,N, ,N,0
T,575,IVAR,RT1.NUM_RUN,number of batches,0xffffffff,N
A,,,,,,,,H_RANGE,,,,,32767
A,,,,,,,,L_RANGE,,,,,0
A,,,,,,,,VALUE,V5,1,N, ,N,5
A,,,,,,,,STATUS,V5,1,N, ,N,5
T,575,IVAR,RT1.FILL_SP,level in tank,0xffffffff,N
A,,,,,,,,H_RANGE,,,,,32767
A,,,,,,,,L_RANGE,,,,,0
A,,,,,,,,VALUE,V6,1,N, ,N,50
A,,,,,,,,STATUS,V6,1,N, ,N,50
T,575,CALC,RT1.TEMP,temp of tank,0xffffffff,N
A,,,,,,,,CHANGE,,,,,1
A,,,,,,,,H_RANGE,,,,,32767
A,,,,,,,,L_RANGE,,,,,0
A,,,,,,,,STATUS,,,,,
A,,,,,,VALUE,V.7,1,Y, ,N,220
T,575,DO,GYLCOL,what is in tank,0xffffffff,N
A,,,,,,,,COMMAND,C17,1,N, ,N,1
A,,,,,,,,STATUS,C17,1,N, ,N,1
T,575,DO,TEG,what is in tank,0xffffffff,N
A,,,,,,,,COMMAND,C18,1,N, ,N,1
A,,,,,,,,STATUS,C18,1,N, ,N,1
T,575,DO,OIL,what is in tank,0xffffffff,N
A,,,,,,,,COMMAND,C19,1,N, ,N,1
A,,,,,,,,STATUS,C19,1,N, ,N,1
T,575,DO,AIR,what is in tank,0xffffffff,N
A,,,,,,,,COMMAND,C20,1,N, ,N,1
A,,,,,,,,STATUS,C20,1,N, ,N,1
T,575,DO,WATER,what is in tank,0xffffffff,N
A,,,,,,,,COMMAND,C21,1,N, ,N,1
A,,,,,,,,STATUS,C21,1,N, ,N,1
T,575,AREA,RT1,recipe to test tistar tags,0xffffffff,N
A,,,,,,,,SCALE_HIGH,,,,,10.0
A,,,,,,,,SCALE_LOW,,,,,0.0
A,,,,,,,,SCALE_FACTOR,,,,,1.0
T,575,DO,RT1.INUSE,recipe to test tistar tags,0xffffffff,N
A,,,,,,,,COMMAND,C23,2,N, ,N,0
A,,,,,,,,STATUS,C23,2,N, ,N,0
Record,Recipe,Component,Tag,Attribute
R,RT1
C,,NUM_RUNS,RT1.NUM_RUNS,VALUE
C,,FILL_SP,RT1.FILL_SP,VALUE
C,,TEMP,RT1.TEMP,STATUS
C,,BATCHES[1],GYLCOL,COMMAND
C,,BATCHES[2],TEG,COMMAND
C,,BATCHES[3],OIL,COMMAND
C,,BATCHES[4],AIR,COMMAND
C,,BATCHES[5],WATER,COMMAND
C,,RT1,RT1.INUSE,COMMAND
Record,GroupNumber,Description
P,1,CLEANING TANK
E
```

The Record line wraps to the second line in this figure.

Figure A-2 *INSTALL.TAG* File Example for PCS 3.x and OSx 4.x

Record	Control-Node	Tag-Type	Tag	Description	Process-Group	Manual-Set	Parent	Attribute	Memory	Locations	Upload	Twenty-%	Autolog	Init–Value
T	575	LOOP	TLOOP	temp loop	0x1	N								
A								CHANGE						1
A								SP	V.1	1	N		N	0
A								STATUS	LSTATUS1	1	N		N	0
A								MODE	LMode1	1	N		N	0
A								L_RANGE	LPVL1	1	Y		N	0
A								H_RANGE	LPVH1	1	Y		N	400
A								PV	LPV1	1	N		N	0
A								ROC_ALM	V.27	1	Y		N	1
A								L_DEV	V.25	1	Y		N	5
A								H_DEV	V.23	1	Y		N	10
A								LL_ALM	V.21	1	Y		N	1
A								L_ALM	V.19	1	Y		N	10
A								H_ALM	V.17	1	Y		N	350
A								HH_ALM	V.15	1	Y		N	380
A								RATE	V.13	1	Y		N	0
A								RESET	V.11	1	Y		N	0.1
A								GAIN	V.9	1	Y		N	10
A								OUT	V.3	1	N		N	0
T	575	DO	TLOOP.NRDY		0x1	N								
A								COMMAND	C22	1	N		N	0
A								STATUS	C22	1	N		N	0
T	575	IVAR	RT1.NUM_RUN	number of batches	0xffffffff	N								
A								H_RANGE						32767
A								L_RANGE						0
A								VALUE	V5	1	N		N	5
A								STATUS	V5	1	N		N	5
T	575	IVAR	RT1.FILL_SP	level in tank	0xffffffff	N								
A								H_RANGE						32767
A								L_RANGE						0
A								VALUE	V6	1	N		N	50
A								STATUS	V6	1	N		N	50
T	575	CALC	RT1.TEMP	temp of tank	0xffffffff	N								
A								CHANGE						1
A								H_RANGE						32767
A								L_RANGE						0
A								VALUE	V.7	1	Y		N	220

Figure A-3 *INSTALL.TAG* File Spreadsheet Example for PCS 3.x and OSx 4.x

Record	Control Node	Tag-Type	Tag	Description	Process-Group	Manual Set	Parent	Attribute	Memory	Locations	Upload	Twenty-%	Autolog	Init-Value
T	575	DO	GYLCOL	what is in tank	0xffffffff	N								
A								COMMAND	C17	1	N		N	1
A								STATUS	C17	1	N		N	1
T	575	DO	TEG	what is in tank	0xffffffff	N								
A								COMMAND	C18	1	N		N	1
A								STATUS	C18	1	N		N	1
T	575	DO	OIL	what is in tank	0xffffffff	N								
A								COMMAND	C19	1	N		N	1
A								STATUS	C19	1	N		N	1
T	575	DO	AIR	what is in tank	0xffffffff	N								
A								COMMAND	C20	1	N		N	1
A								STATUS	C20	1	N		N	1
T	575	DO	WATER	what is in tank	0xffffffff	N								
A								COMMAND	C21	1	N		N	1
A								STATUS	C21	1	N		N	1
T	575	AREA	RT1	recipe	0xffffffff	N								
A								SCALE_HIGH						10.0
A								SCALE_LOW						0.0
A								SCALE_FACTOR						1.0
T	575	DO	RT1.INUSE	recipe in use	0xffffffff	N								
A								COMMAND	C23	2	N		N	0
A								STATUS	C23	2	N		N	0

Record	Recipe	Component	Tag	Attribute										
R	RT1													
C		Num Runs	RT1.NUM_RUNS	Value										
C		Fill_Sp	RT1.FILL_SP	Value										
C		Temp	RT1.TEMP	Status										
C		Batches (1)	GLYCOL	Command										
C		Batches (2)	TEG	Command										
C		Batches (3)	OIL	Command										
C		Batches (4)	AIR	Command										
C		Batches (5)	WATER	Command										
C		RT1	RT1.INUSE	Command										

Record	Group-Number	Description												
P	1	Clean Tank												
E														

Figure A-3 *INSTALL.TAG* File Spreadsheet Example for PCS 3.x and OSx 4.x (continued)

An Analysis of the *INSTALL.TAG* File Examples for PCS/OSx

Consider the **install.tag** file example shown in Figure A-2 and Figure A-3. There are 12 process tags, one recipe, and one process group. The recipe, RT1, is an area tag with eight components. The process group is called Clean Tank.

The two tags, RT1.NUM_RUN and RT1.FILL_SP, are integers. Each tag has an initial value of zero. They are both a part of the recipe, RT1. The Series 505 address of RT1.NUM_RUN is V5, and RT1.FILL_SP is V6, as listed under the VALUE and STATUS attributes.

The tag called RT1.TEMP is a real number. It has an initial value of zero, and its Series 505 address is assigned to the VALUE attribute as V.7, which is to say that RT1.TEMP actually takes up the addresses V7 and V8. It is also used in the recipe RT1. Five boolean variables, GLYCOL, TEG, OIL, AIR, and WATER, are used in the recipe RT1. Their Series 505 addresses are assigned to COMMAND and STATUS as C17, C18, C19, C20, and C21, respectively. The VALUE attribute is passed for the reals and integers and the COMMAND attribute is passed for the booleans.

The components in the recipe are listed in the component section under recipe RT1. You can see the APT name under the component name and the PCS/OSx name under the tag name.

The name of the loop is TLOOP, and it is a LOOP tag type. TLOOP is a temperature control loop assigned to process group #1, Clean Tank. The number immediately following the word LMode in the MODE attribute identifies the address of the loop in the controller, that is, Loop1. Many loop attributes are passed to PCS/OSx.

The process group numbers are in hexadecimal form. There are 32 process groups. Process group number 0 x 1 refers to only using process group #1. Process group number 0 x ffff ffff means that the tag was assigned to all 32 process groups.

The PCS/OSx **install.tag** file shown in Figure A-2 and Figure A-3 is for a Series 505 controller. An **install.tag** file for an S5 controller is exactly the same, except that the memory addresses follow S5 conventions.

INSTALL.TAG File: (First Line) The first line of a section starts with a field description line and contains a description of the data in the columns. Compare the first line in Figure A-2 with the material in the first row in Figure A-3.

INSTALL.TAG File: (Second Line) The second line of the section determines the amount of information associated with each tag. Compare the second line in Figure A-2 with the second row in Figure A-3. This line starts with a T, P or R identifier to identify it as a tag, process group, or recipe, as shown in Table A-4.

Table A-4 Identifiers for Tag Types

Identifier	Meaning	Field Contents
T	Tag	Controller Type, Tag Name, Description, Manual Set, Process Group Number (in Hex) and Parent
P	Process group	Process Group Number (in Hex) and Name
R	Recipe	Recipe Name

INSTALL.TAG File: (Subsequent Lines) The next several lines of a section start with different identifiers depending upon the tag type (A or C), and contain attribute information for the tag or recipe listed in the **install.tag** file. See Table A-5. The number of lines for each tag varies with the tag type.

Table A-5 Identifiers for Attributes of Tags

Identifier	Meaning	Field Contents*
A	Attribute of Tag	Attribute Name, Memory Location, Number of Memory Locations, Upload, 20% Offset, Autolog, and Initial Value
C	Components in a recipe	Component Name, Tag Name, Attribute (VALUE, STATUS or COMMAND)
* Upload, 20% Offset, and Autolog can be a Y for yes, N for no, or blank for not applicable.		

INSTALL.TAG File: (Last Line) The last line of the file starts with an E identifier, which means end-of-file.

APT determines the PCS/OSx tag types based on the type of variable the tag is. See Table A-6.

Table A-6 PCS/OSx Tag Types

Tag Type	Acronym	Tag Type	Acronym
Recipe area name	AREA	Timer	TMR
Real variable	CALC	Counter	CTR
Integer variable	IVAR	APT valve device	VLV1
Digital output	DO	APT valve device	VLV2
Digital input or APT flag	DI	APT motor device	MTR1
PID loop	LOOP	APT motor device	MTR2
Analog alarm or analog input	AI	APT reversible motor device	RMTR
Analog output	AO	Digital output array of 10	DO10
Text	TEXT	Digital input array of 10	DI10

The PCS/OSx attributes that are reported include: STATUS, VALUE, COMMAND, SETPOINT, OVERRIDE, MODE_CMMD, L_RANGE, H_RANGE, MODE, PV, SP, OUT, ROC_ALRM, DEV, H_DEV, etc. For each attribute, six types of data are stored.

Appendix B

Extensions Fixed by the Compile

When you mark a complex object, such as a valve or motor, only a subset of the tag extension addresses is fixed. A detailed list of these appears in the pages that follow.

Declarations

Declaration Types

Type (All declarations of the following types that were marked for translation**.)**

Integer	Shift Register Array
Real	Scaled Integer
Boolean	DI10
Flag	DO10
Text	Text Array
Integer Array	
Real Array	
Boolean Array	
Sequence Array	

Fast/Slow Timer, Counter Extensions

Read-only Boolean	Read-only Integer	Read-only Real
	.TCC	

Read/Write Boolean	Read/Write Integer	Read/Write Real
.RESET	.TCP	
.ENABL		
.INPUT		

I/O and Modules

AI Extensions

Read-only Boolean	Read-only Integer	Read-only Real
	.RAW	I/O name

BI Extensions

Read-only Boolean	Read-only Integer	Read-only Real
	.RAW	I/O name

I/O Symbolic Names

I/O Point (All I/O points of the following types that were marked for translation**.)**

Analog Input
Analog Output
Binary-coded Decimal Input
Binary-coded Decimal Output
Digital Flag
Digital Input
Digital Output
Resistance Temperature Detector
Thermocouple
Word Input
Word Output

Devices

Valve Extensions

Boolean Extension	Valve Types							
Position bits (read-only)								
.OPND	VND	VSN	VSS	VSD	VDD	VMD	BV1/2	VUD
.CLSD	VND	VSN	VSS	VSD	VDD	VMD	BV1/2	VUD
.TRVL		VSN	VSS	VSD	VDD	VMD	BV1/2	VUD
Fail bits (read-only)								
.FTO			VSS	VSD	VDD	VMD	BV1/2	VUD
.FTC			VSS	VSD	VDD	VMD	BV1/2	VUD
.FAILD	VND			VSD	VDD	VMD	BV1/2	VUD
Operation bits (read/write)								
.DSBLD		VSN	VSS	VSD	VDD	VMD	BV1/2	VUD
.LOCKD		VSN	VSS	VSD	VDD	VMD	BV1/2	VUD
.NRDY		VSN	VSS	VSD	VDD	VMD	BV1/2	VUD
.MOPEN	VND	VSN	VSS	VSD	VDD	VMD	BV1/2	VUD
Override bits (read/write)								
.OVRD			VSS					
.OVRDO				VSD	VDD	VMD		VUD
.OVRDC				VSD	VDD	VMD		VUD
.OVRDL							BV1/2	
.OVRDH							BV1/2	

Motor Extensions

Boolean Extension	Motor Types						
Position bits (read-only)							
.RUNNG	MSN	MSS	MDN	MDS	RM1/2	TS1/2	MUD
.STPPD	MSN	MSS	MDN	MDS	RM1/2	TS1/2	MUD
.TRVL	MSN	MSS	MDN	MDS	RM1/2	TS1/2	MUD
Fail bits (read-only)							
.FTR		MSS		MDS	RM1/2	TS1/2	MUD
.FTS		MSS		MDS	RM1/2	TS1/2	MUD
Operation bits (read/write)							
.DSBLD	MSN	MSS	MDN	MDS	RM1/2	TS1/2	MUD
.LOCKD	MSN	MSS	MDN	MDS	RM1/2	TS1/2	MUD
.NRDY	MSN	MSS	MDN	MDS	RM1/2	TS1/2	MUD
.MSTRT	MSN	MSS	MDN	MDS	RM1/2	TS1/2	MUD
.MREV					RM1/2		
.MHIGH						TS1/2	

Devices (continued)

Cylinder Extensions

Boolean Extension	Valve Types	
Position bits (read-only)		
.EXTENDED	CSD	CUD
.RETRACTED	CSD	CUD
.TRVL	CSD	CUD
Fail bits (read-only)		
.FTE	CSD	CUD
.FTR	CSD	CUD
.FAILD	CSD	CUD
Operation bits (read/write)		
.DSBLD	CSD	CUD
.LOCKD	CSD	CUD
.NRDY	CSD	CUD
.MEXTEND	CSD	CUD
Override bits (read/write)		
.OVRDE	CSD	CUD
.OVRDE	CSD	CUD

Press Extensions

Boolean Extension	Valve Types							
Position bits (read-only)								
.UP	PND	PSN	PSS	PSD	PDD	PMD	PS1/2	PUD
.DOWN	PND	PSN	PSS	PSD	PDD	PMD	PS1/2	PUD
.TRVL		PSN	PSS	PSD	PDD	PMD	PS1/2	PUD
Fail bits (read-only)								
.FTR			PSS	PSD	PDD	PMD	PS1/2	PUD
.FTL			PSS	PSD	PDD	PMD	PS1/2	PUD
.FAILD	PND			PSD	PDD	PMD	PS1/2	PUD
Operation bits (read/write)								
.DSBLD		PSN	PSS	PSD	PDD	PMD	PS1/2	PUD
.LOCKD		PSN	PSS	PSD	PDD	PMD	PS1/2	PUD
.NRDY		PSN	PSS	PSD	PDD	PMD	PS1/2	PUD
.MRAISE	PND	PSN	PSS	PSD	PDD	PMD	PS1/2	PUD
Override bits (read/write)								
.OVRD			PSS					
.OVRDU				PSD	PDD	PMD		PUD
.OVRDD				PSD	PDD	PMD		PUD
.OVRDL							PS1/2	PUD
.OVRDH							PS1/2	PUD

Stopwatch Commands and Extensions

Read-only Boolean	Read-only Integer	Read-only Real
.RUNNG		
.HOLD		
.MAXC		
.TOUT		

Read/Write Boolean	Read/Write Integer	Read/Write Real
	.CUR	
	.PSET	

Standard Blocks

Analog Alarm Extensions

Read-only Boolean	Read-only Integer	Read-only Real
.DSABL		
.INHHA		
.INHA		
.INLA		
.INLLA		
.INYDA		
.INODA		
.INRCA		
.INBTA		
.OVRUN		

Read/Write Boolean	Read/Write Integer	Read/Write Real
.ENABL		.APV
.NRDY		.PVH
		.PVL
		.HHA
		.HA
		.LA
		.LLA
		.ODA
		.YDA
		.RCA
		.SP

PID Extensions

Read-only Boolean	Read-only Integer	Read-only Real
	.IOUT	.OUT

Read/Write Boolean	Read/Write Integer	Read/Write Real
.NRDY	.AWS	.LPV
		.HLIM
		.LLIM
		.PVH
		.PVL
		.KC
		.TI
		.TD
		.HHA
		.HA
		.LA
		.LLA
		.ODA
		.YDA
		.RCA
		.SP

On/Off Extensions

Same as PID with following exceptions.

Read-only Boolean	Read-only Integer	Read-only Real
	minus .IOUT	

Advanced Blocks

Dead Time Compensator Extensions

Same as PID plus the following.

Read/Write Boolean	Read/Write Integer	Read/Write Real
		.GAIN .TAU1 .TAU2 .DTIME

Dual Mode Extensions

Same as PID plus the following.

Read/Write Boolean	Read/Write Intege	Read/Write Real
	.DMODE	.PRSET .DLY1 .DLY2

Feedforward Output Adjust Extensions

Same as PID plus the following.

Read-only Boolean	Read-only Integer	Read-only Real
		.SOUT

Read/Write Integer	Read/Write Integer	Read/Write Real
.FMODE		.GAIN .TAU1 .TAU2 .TLEAD .DTIME

Feedforward Setpoint Adjust Extensions

Same as PID plus the following.

Read/Write Integer	Read/Write Integer	Read/Write Real
		.GAIN .TAU1 .TAU2 .TLEAD .DTIME

Ratio Station Extensions

Same as PID plus the following.

Read-only Boolean	Read-only Integer	Read-only Real
		.RATIO

Read/Write Boolean	Read/Write Integer	Read/Write Real
		.OFFST

Math Control Blocks

Absolute Value, Square, Square Root Extensions

Read-only Boolean	Read-only Integer	Read-only Real
	.IOUT	.OUT

Read/Write Boolean	Read/Write Integer	Read/Write Real
	.IIN	.IN

Divider, Multiplier, Subtractor, Summer Extensions

Read-only Boolean	Read-only Integer	Read-only Real
	.IOUT	.OUT

Read/Write Boolean	Read/Write Integer	Read/Write Real
	.IIN1 .IIN2	.IN1 .IN2

Math Block Extensions

Read-only Boolean	Read-only Integer	Read-only Real
.ENABLD	.IOUT1 .IOUT2 .IOUT3 .IOUT4	.OUT1 .OUT2 .OUT3 .OUT4

Read/Write Boolean	Read/Write Integer	Read/Write Real
.ENABL .NRDY	.IIN1 .IIN2 .IIN3 .IIN4	.IN1 .IN2 .IN3 .IN4

Dynamic Blocks

Dead Time Delay Extensions

Read-only Boolean	Read-only Integer	Read-only Real
.ENABLD	.IOUT	.OUT

Read/Write Boolean	Read/Write Integer	Read/Write Real
.ENABL .NRDY		.IN .OUTIC .GAIN .DTIME

Dynamic Blocks (continued)

Derivative Extensions

Read-only Boolean	Read-only Integer	Read-only Real
.ENABLD	.IOUT	.OUT

Read/Write Boolean	Read/Write Integer	Read/Write Real
.ENABL .NRDY		.IN

Integrator Extensions

Read-only Boolean	Read-only Integer	Read-only Real
.ENABLD	.IOUT	.OUT

Read/Write Boolean	Read/Write Integer	Read/Write Real
.ENABL .NRDY		.IN .OUTIC .TAU1 .DTIME .GAIN

First Order Lag Extensions

Read-only Boolean	Read-only Integer	Read-only Real
.ENABLD	.IOUT	.OUT

Read/Write Boolean	Read/Write Integer	Read/Write Real
.ENABL .NRDY		.IN .OUTIC .GAIN .TAU1 .DTIME

First Order Lead/Lag Extensions

Same as 1st Order Lag.

Second Order Lag Extensions

Same as 1st Order Lag.

Second Order Lead/Lag Extensions

Same as 1st Order Lag.

Valve Control Blocks

Motor Position Control Extensions

Read-only Boolean	Read-only Integer	Read-only Real
		.PV

Read/Write Boolean	Read/Write Integer	Read/Write Real
.ENABL .NRDY		.SP .DBAND

Valve Sequencer Extensions

Read-only Boolean	Read-only Integer	Read-only Real
	.IOUT	.OUT

Read/Write Boolean	Read/Write Integer	Read/Write Real
.ENABL .NRDY .DOUT		.IN .BRKPH .BRKPL

Proportional Time Control Extensions

Read-only Boolean	Read-only Integer	Read/Write Real
.DOUT		

Read/Write Boolean	Read/Write Integer	Read/Write Real
.ENABL .NRDY		.IN .DUTY

Split Range Extensions

Read-only Boolean	Read-only Integer	Read-only Real
	.IOUT1 .IOUT2	.OUT1 .OUT2

Read/Write Boolean	Read/Write Integer	Read/Write Real
.ENABL .NRDY		.IN .BRKP1 .BRKP2

Selector Blocks

Average Selector Extensions

Read-only Boolean	Read-only Integer	Read-only Real
	.IOUT .POS .STAT	.OUT

Read/Write Boolean	Read/Write Integer	Read/Write Real
.ENABL .NRDY	.IIN1 .IIN2 .IIN3	.IN1 .IN2 .IN3 .TVAL

High Selector Extensions
Low Selector Extensions

Read-only Boolean	Read-only Integer	Read-only Real
	.IOUT .POS	.OUT

Read/Write Boolean	Read/Write Integer	Read/Write Real
.ENABL .NRDY	.IIN1 .IIN2 .IIN3 .IIN4 .SW1 .SW2 .SW3 .SW4	.IN1 .IN2 .IN3 .IN4

Inswitch Selector Extensions

Read-only Boolean	Read-only Integer	Read-only Real
	.IOUT	.OUT

Read/Write Boolean	Read/Write Integer	Read/Write Real
.ENABL .NRDY	.IIN1 .IIN2 .IIN3 .IIN4 .POS	.IN1 .IN2 .IN3 .IN4

Median Selector Extensions

Read-only Boolean	Read-only Integer	Read-only Real
	.IOUT .POS	.OUT

Read/Write Boolean	Read/Write Integer	Read/Write Real
.ENABL .NRDY	.IIN1 .IIN2 .IIN3	.IN1 .IN2 .IN3

Selector Blocks (continued)

Outswitch Selector Extensions

Read/Write Boolean	Read/Write Integer	Read/Write Real
.ENABL .NRDY	.IIN1 .POS	.IN .PV1 .PV2 .PV3 .PV4

Threshold Selector Extensions

Read-only Boolean	Read-only Integer	Read-only Real
.DOUT		

Read/Write Boolean	Read/Write Integer	Read/Write Real
.ENABL .NRDY	.IIN	.IN .LIMIT

Other Control Blocks

Anti-reset Windup/Constraint Extensions

Read/Write Boolean	Read/Write Integer	Read/Write Real
.ENABL .NRDY		.HLIM .LLIM

Anti-reset Windup/Select Extensions

Read/Write Boolean	Read/Write Integer	Read/Write Real
.ENABL .NRDY		

Correlated Lookup Table Extensions

Read-only Boolean	Read-only Integer	Read-only Real
	.IOUT	.OUT

Read/Write Boolean	Read/Write Integer	Read/Write Real
.ENABL .NRDY		.IN

Scale Extensions

Read-only Boolean	Read-only Integer	Read-only Real
	.IOUT	.OUT

Read/Write Boolean	Read/Write Integer	Read/Write Real
.ENABL .NRDY	.IIN	.IN .HRIN .LRIN .HROUT .LROUT

Limiter Blocks

Output Limiter Extensions

Read-only Boolean	Read-only Integer	Read-only Real
	.IOUT	.OUT

Read/Write Boolean	Read/Write Integer	Read/Write Real
.ENABL .NRDY	.IIN	.IN .HLIM .LLIM

Rate Limiter Extensions

Read-only Boolean	Read-only Integer	Read-only Real
	.IOUT	.OUT

Read/Write Boolean	Read/Write Integer	Read/Write Real
.ENABL .NRDY	.IIN	.IN .RLIM

Unit Extensions

.ENABL
.ABORT

Appendix C

OSx, PCS, and TISTAR Tag Translation

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C.1 Translating APT Objects to OSx, PCS, and TISTAR

Overview

APT allows you to translate APT names to OSx 4.x, PCS 3.x, and TISTAR 1.x and 2.x. In this appendix, the name OSx refers to OSx 4.x, PCS Rel. 3.x, and TISTAR Rel. 1.x and 2.x, unless otherwise noted. The translation process involves the following steps:

- Specify the names you want to translate to OSx. Once you mark a tag, APT provides default names for the OSx name and the OSx object.
- Mark complicated tags such as devices, I/O points, or declarations with more than one associated tag.
- Specify scan status, upload, autoload (OSx 4.x and PCS 3.x), and download (TISTAR 1.x and 2.x), or 20% offset for each point. APT does provide defaults depending on the object type.

After tags are translated to OSx, they are stable; that is, they keep the same controller location when the program is changed or recompiled. If you mark new tags, change reserved memory locations or cause the compile phase six to force compile, the tags must be translated again.

NOTE: Objects that you mark for OSx cannot be deleted unless you unmark them and then select the **Delete unused tags on secondary** option during translate.

When you translate values that are defined with a high and low range, the low range cannot be greater than the value that you enter in the APT form.

Units

You can translate the unit extensions to OSx by marking the unit in the Program Content Directory. Table C-1 lists the OSx tag type and the unit extensions.

Table C-1 Unit Tag Types and Extensions

OSx Type	APT Extension	OSx Attributes	Descriptor
do	**.ENABL**	Status	Unit enabled status
		Command	Unit enable/disable command
do	**.ABORT**	Status	Unit abort status
		Command	Unit abort/clrabort command
unit	*Unit name (no extension)*		Unit tag on OSx
	Unit name.**STATUS**	Status	Current status
	Unit name.**COMMAND**	Command	Command request
	Unit name.**MODE_CMD**	Mode_cmd	Mode request
	No extension available	Operation	Current operation
	No extension available	Type	Type
	Unit name.**BCH_REQ**	Bch_req	Batch request
	Unit name.**BCH_REQ_INFO**	Bch_req_info	Batch information
	Unit name.**BCH_REQ_RESP**	Bch_req_resp	Response to batch request

Batch Unit Tags

The controller can retain the batch control in OSx, but still allow OSx to assist in batch tracking/reports, through the use of three attributes available in the **UNIT TAG**. See Table C-2 for the **.BCH_REQ**, **.BCH_REQ_RESP**, and **.BCH_REQ_INFO** unit tag attributes.

The controller program can set these attributes as needed to perform the appropriate connections between the control node and the operations node. OSx uses its database to log batch changes and to create batch reports. Making batch requests in the controller by way of **unit_name.BCH_REQ** allows OSx to notify its database of the actions taking place in the controller and keep appropriate records of what is happening during the batch. The **unit_name.BCH_REQ** inputs the numerical equivalents of the commands for the batches. These numbers are listed in the *SIMATIC PCS 7 OSx Batch Programming Manual*.

Table C-2 Batch Unit Tag Attributes

Attributes	Description	Values
BCH_REQ	batch request	integer value (–32768 to 32767)
BCH_REQ_RESP	batch request response	successful transfer (8000H) failed transfer (4000H) no command (0000H)
BCH_REQ_INFO	batch request information	up to 16 characters

Each time the **.BCH_REQ** is sent to a batch or unit command, the OSx batch manager processes the command and then writes successful (8000H) or failed (4000H) to the **unit_name.BCH_REQ_RESP**. A value of 8000H (successful) does not mean that the requested command was actually successfully executed; it means that the batch manager successfully read the request and passed it along to the batch and/or unit. Typically, the controller sets **.BCH_REQ_RESP** to no command (0000H) before a batch request.

If you need to send additional information with the **.BCH_REQ** through the **.BCH_REQ_INFO**, you can enter up to 16 characters in **.BCH_REQ_INFO**.

Devices

When you translate devices to OSx, APT automatically creates the associated extensions. Table C-3 through Table C-7 list the devices and how they translate to OSx.

Table C-3 Valves

OSx Type	Device Type	Descriptor
vlv1	VSN	Single or Null Feedback Valve
vlv1	VSS	Single or Null Feedback Valve
vlv2	VND	Dual Feedback Valve
vlv2	VSD	Dual Feedback Valve
vlv2	VDD	Dual Feedback Valve
vlv2	VMD	Dual Feedback Valve
mtr2	BV1	Three-Position Valve
mtr2	BV2	Three-Position Valve
vlv2	VUD	User-defined Valve

Table C-4 Cylinders

OSx Type	Device Type	Descriptor
vlv2	CSD	Cylinder
vlv2	CUD	User-defined Cylinder

Table C-5 Motors

OSx Type	Device Type	Descriptor
mtr1	MDN	Non-Reversible Motor
mtr1	MDS	Non-Reversible Motor
mtr1	MSN	Non-Reversible Motor
mtr1	MSS	Non-Reversible Motor
mtr1	MUD	User-defined Motor
rmtr	RM1	Reversible Motor
rmtr	RM2	Reversible Motor
mtr2	TS1	Two-Speed Motor
mtr2	TS2	Two-Speed Motor

Table C-6 Presses

OSx Type	Device Type	Descriptor
vlv1	PSN	Single or Null Feedback Press
vlv1	PSS	Single or Null Feedback Press
vlv2	PND	Hand-operated Press/Dual Feedback
vlv2	PSD	Dual Feedback Press
vlv2	PDD	Dual Feedback Press
vlv2	PMD	Dual Feedback Press
mtr2	PS1	Three-Position Press
mtr2	PS2	Three-Position Press
vlv2	PUD	User-defined Press

Table C-7 Stopwatch Timer

OSx Type	Extension	Descriptor
ivar	**.PSET**	Timer Preset
ivar	**.CUR**	Timer Current
di	**.RUNNG**	Timer Running
di	**.HOLD**	Hold Timer
di	**.MAXC**	Maximum Count
di	**.TOUT**	Time Out

Correlating APT Device Types with OSx/PCS Attributes

The information in this section provides bit-by-bit correspondence between APT device types and OSx tag type attribute.

Translating Tags for OSx/PCS MTR1

The OSx MTR1 corresponds to the APT MSN, MSS, MDS, MDN, and MUD motor types. Figure C-1 shows the MTR1 status word.

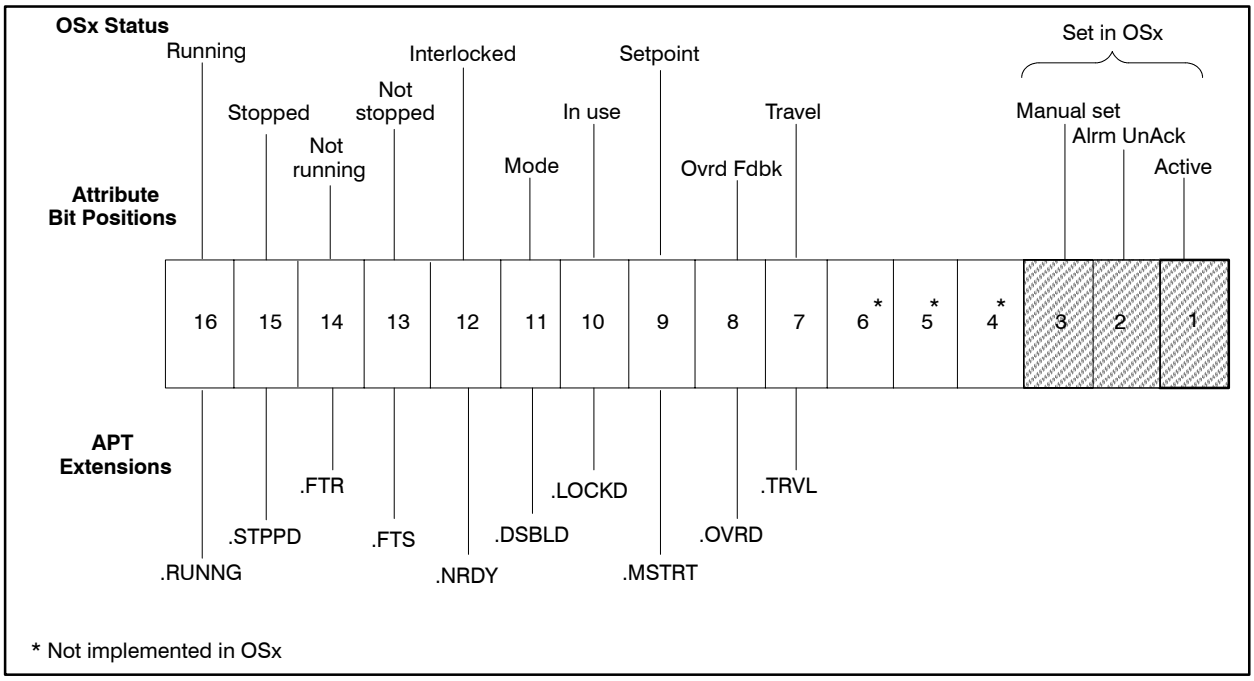

Figure C-1 APT Tag Correlation with OSx MTR1 Status Word

Table C-8 shows the APT extension correlation with OSx MRT1 attributes.

Table C-8 APT Tag Correlation with OSx MTR1 Attributes

OSx Attribute	OSx Command Form Data Written to Controller	OSx Status Bit Data Read from Controller [1]	APT Extension [2]
Override P/C Memory Location: C of Length 1	-32768 (Disable)	8 = 1	Mxx.**OVRD** = 1
Mode_Cmd P/C Memory Location: C of Length 2	-32768 (Disable) 16384 (Lock) 0 (Unlock)	11 = 1 10 = 1 10 = 0	Mxx.**DSBLD** = 1 Mxx.**LOCKD** = 1 Mxx.**LOCKD** = 0
Setpoint PC Memory Location: C of Length 1	-32768	9 = 1	Mxx.**MSTRT** = 1
Timeout_1 [3] P/C Memory Location: TCP	Integer × 0.1 sec	Not implemented in OSx status word	Mxx.**RTCP**
Timeout_2 [3] P/C Memory Location: TCP	Integer × 0.1 sec	Not implemented in OSx status word	Mxx.**STCP**

1 Refer to Figure C-1.

2 Mxx represents MSN, MSS, MDS, MDN, or MUD

3 For OSx the Timeout_1 and Timeout_2 attributes are reflected in the status word via the combination of the running and stopped bits, as shown below.

MTR1		
Running	Stopped	State
1	0	Running
0	1	Stopped
0	0	Travel

Translating Tags for OSx/PCS RMTR

The OSx RMTR corresponds to the APT RM1 and RM2 motor types. Figure C-2 shows the RMTR status word.

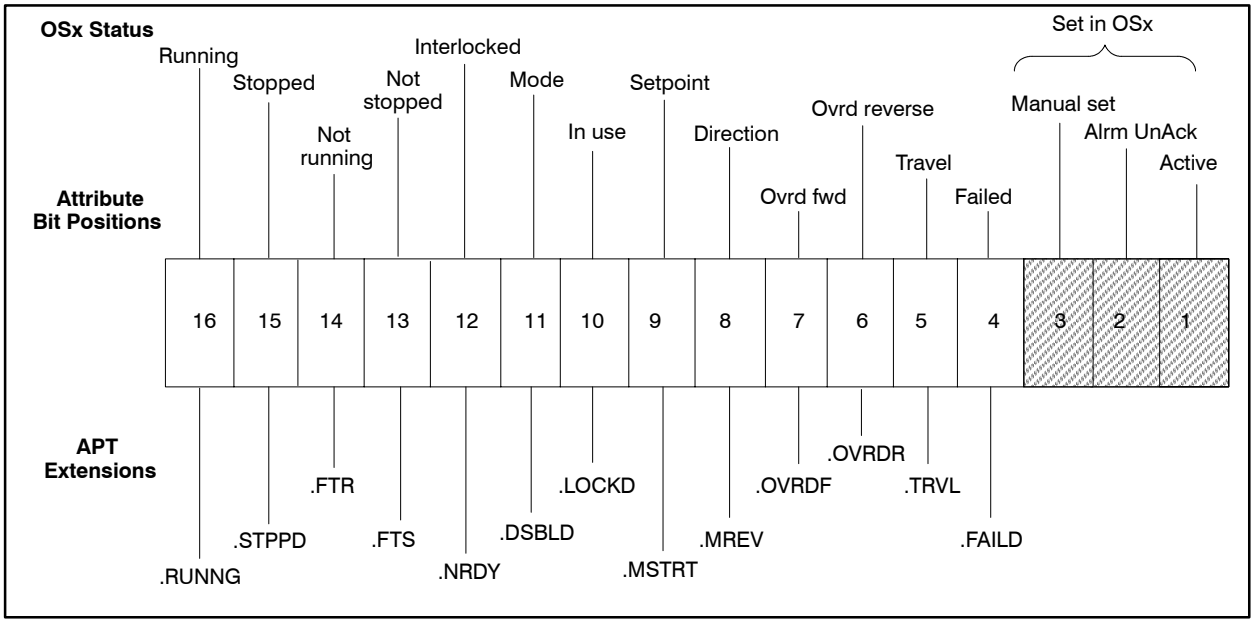

Figure C-2 APT Tag Correlation with OSx RMTR Status Word

Table C-9 shows the APT extension correlation with OSx RMTR attributes.

Table C-9 APT Tag Correlation with OSx RMTR Attributes

OSx Attribute	OSx Command Form Data Written to Controller	OSx Status Bit Data Read from Controller [1]	APT Extension [2]
Override P/C Memory Location: C of Length 2	-32768 (Forward) 16384 (Reverse) -16384 (Both) 0 (Neither)	7 = 1 6 = 1 7 = 1 6 = 1 7 = 0 6 = 0	RMx.**OVRDF** = 1 RMx.**OVRDR** = 1 RMx.**OVRDF** = 1 RMx.**OVRDR** = 1 RMx.**OVRDF** = 0 RMx.**OVRDR** = 0
Mode_Cmd P/C Memory Location: C of Length 2	-32768 (Disable) 16384 (Lock) 0 (Unlock)	11 = 1 10 = 1 10 = 0	RMx.**DSBLD** = 1 RMx.**LOCKD** = 1 RMx.**LOCKD** = 0
Setpoint PC Memory Location: C of Length 2	-32768 (Forward) -16384 (Reverse) 0 (Stop)	9 = 1 8 = 1 9 = 0 8 = 0	RMx.**MSTRT** = 1 RMx.**MREV** = 1 RMx.**MSTRT** = 0 RMx.**MREV** = 0
Timeout_1 [3] P/C Memory Location: TCP	Integer × 0.1 sec	Not implemented in OSx status word	RMx.**RTCP**
Timeout_2 [3] P/C Memory Location: TCP	Integer × 0.1 sec	Not implemented in OSx status word	RMx.**STCP**

1 Refer to Figure C-2.

2 RMx represents RM1 or RM2.

3 For OSx the Timeout_1 and Timeout_2 attributes are reflected in the status word via the combination of the running and stopped bits, as shown below.

RMTR		
Running	Stopped	State
1	0	Running
0	1	Stopped
0	0	Travel
1	1	Failed

Translating Tags for OSx/PCS MTR2

The OSx MTR2 corresponds to the APT BV1 and BV2 valve types, PS1 and PS2 press types, and TS1 and TS2 motor types. Figure C-3 shows the MTR2 status word.

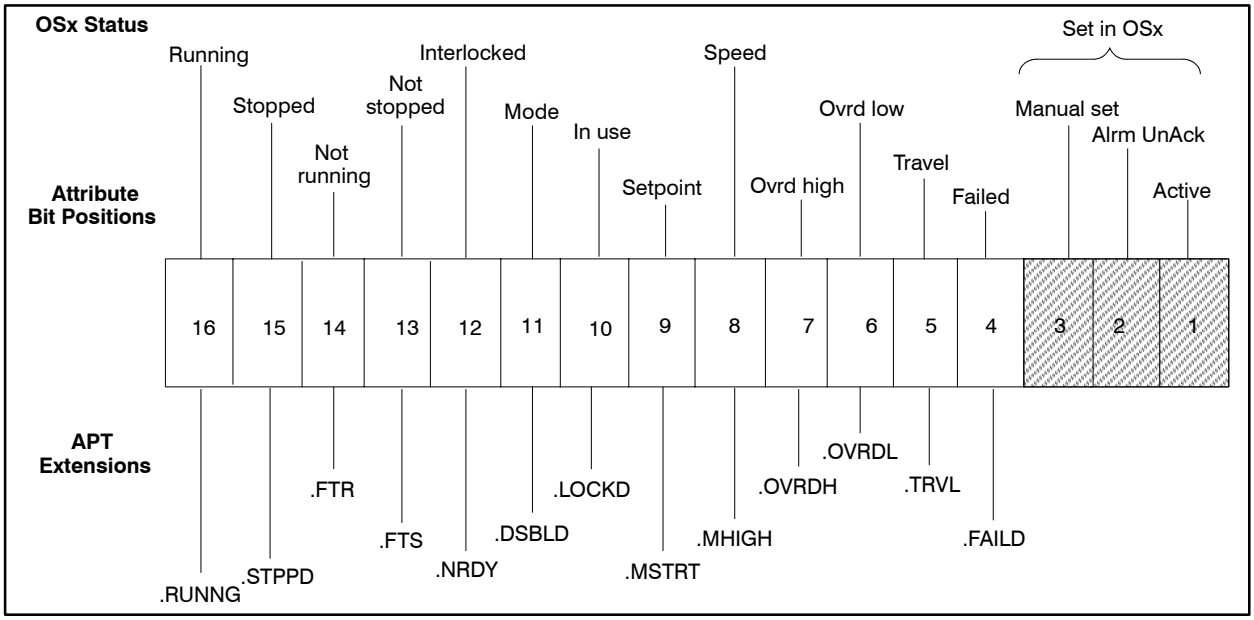

Figure C-3 APT Tag Correlation with OSx MTR2 Status Word

Table C-10 shows the OSx MTR2 status correlation with APT extensions.

Table C-10 OSx MTR2 Status Correlation with APT Extensions

OSx Status	Bit	APT Ext - BV1	APT Ext - BV2	APT Ext - PS1	APT Ext - PS2	APT Ext - TS1	APT Ext - TS2
Running	16	.OPND	.OPND	.UP	.UP	.RUNNG	.RUNNG
Stopped	15	.CLSD	.CLSD	.DOWN	.DOWN	.STPPD	.STPPD
Not Running	14	.FTO	.FTO	.FTR	.FTR	.FTR	.FTR
Not Stopped	13	.FTC	.FTC	.FTL	.FTL	.FTS	.FTS
Interlocked	12	.NRDY	.NRDY	.NRDY	.NRDY	.NRDY	.NRDY
Mode	11	.DSBLD	.DSBLD	.DSBLD	.DSBLD	.DSBLD	.DSBLD
In Use	10	.LOCKD	.LOCKD	.LOCKD	.LOCKD	.LOCKD	.LOCKD
Setpoint	9	.MOPEN	.MOPEN	.MRAISE	.MRAISE	.MSTRT	.MSTRT
Speed	8	.MHIGH	.MHIGH	.MHIGH	.MHIGH	.MHIGH	.MHIGH
Ovrd High	7	.OVRDH	.OVRDH	.OVRDH	.OVRDH	.OVRDH	.OVRDH
Ovrd Low	6	.OVRDL	.OVRDL	.OVRDL	.OVRDL	.OVRDL	.OVRDL
Travel	5	.TRVL	.TRVL	.TRVL	.TRVL	.TRVL	.TRVL
Failed	4	.FAILD	.FAILD	.FAILD	.FAILD	.FAILD	.FAILD

Table C-11 shows the APT extension correlation with OSx MTR2 attributes.

Table C-11 APT Tag Correlation with OSx MTR2 Attributes

OSx Attribute	OSx Command Form Data Written to Controller	OSx Status Bit Data Read from Controller [1]	APT Extension [2]
Override P/C Memory Location: C of Length 2	-32768 (High) 16384 (Low) -16384 (Both) 0 (Neither)	7 = 1 6 = 1 7 = 1 6 = 1 7 = 0 6 = 0	TSx.**OVRDH** = 1 TSx.**OVRDL** = 1 TSx.**OVRDH** = 1 TSx.**OVRDL** = 1 TSx.**OVRDH** = 0 TSx.**OVRDL** = 0
Mode_Cmd P/C Memory Location: C of Length 2	-32768 (Disable) 16384 (Lock) 0 (Unlock)	11 = 1 10 = 1 10 = 0	TSx.**DSBLD** = 1 TSx.**LOCKD** = 1 TSx.**LOCKD** = 0
Setpoint PC Memory Location: C of Length 2	-32768 (Low) -16384 (High) 0 (Stop)	9 = 1 8 = 1 9 = 0 8 = 0	TSx.**MSTRT** = 1 TSx.**MHIGH** = 1 TSx.**MSTRT** = 0 TSx.**MHIGH** = 0
Timeout_1 [3] P/C Memory Location: TCP	Integer × 0.1 sec	Not implemented in OSx status word	TSx.**RTCP**
Timeout_2 [3] P/C Memory Location: TCP	Integer × 0.1 sec	Not implemented in OSx status word	TSx.**STCP**

1 Refer to Figure C-3.

2 TSx represents TS1 or TS2. For the valve, the setpoint extensions are Vx.**MOPEN** and Vx.**MHIGH** and the timeout extensions are Vx.**OTCP** and Vx.**CTCP**. For the press, the setpoint extensions are Px.**MRAISE** and Px.**MHIGH** and the timeout extensions are Px.**UTCP** and Px.**DTCP**.

3 For OSx the Timeout_1 and Timeout_2 attributes are reflected in the status word via the combination of the running and stopped bits, as shown below.

MTR2		
Running	Stopped	State
1	0	Running
0	1	Stopped
0	0	Travel
1	1	Failed

Translating Tags for OSx/PCS VLV1

The OSx VLV1 corresponds to the APT VSN and VSS valve types and PSN and PSS press types. Figure C-4 shows the VLV1 status word.

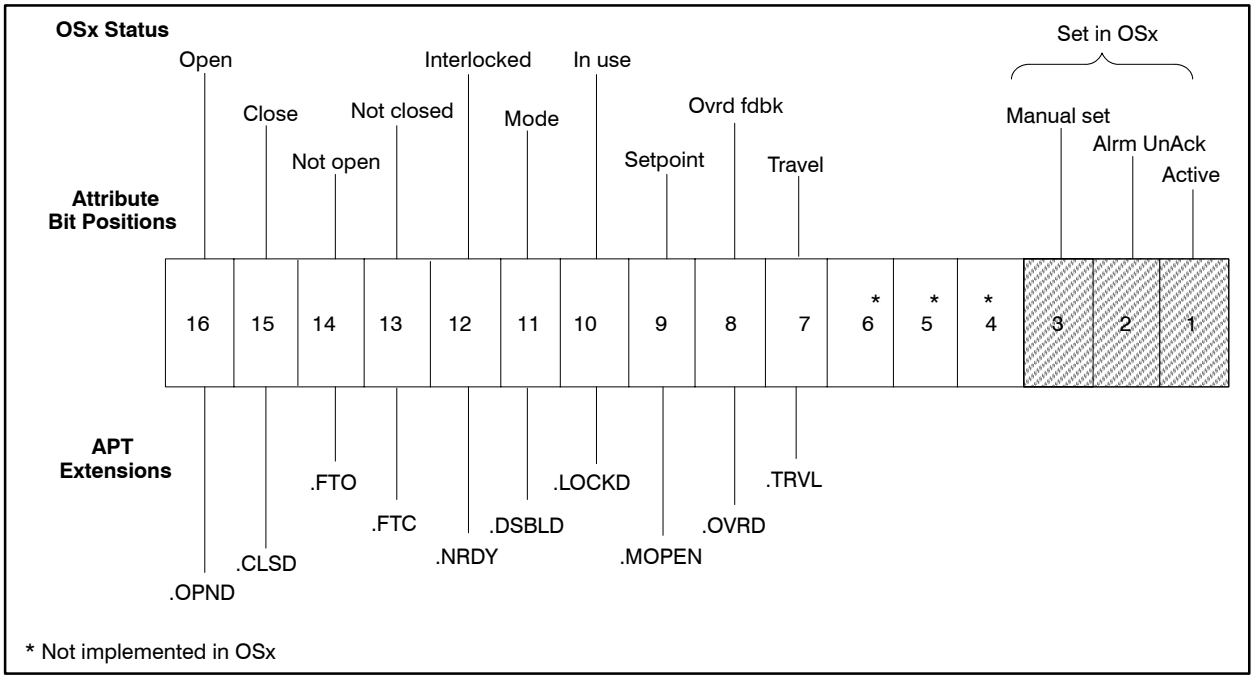

Figure C-4 APT Tag Correlation with OSx VLV1

Table C-12 shows the APT extension correlation with OSx VLV1 attributes.

Table C-12 APT Tag Correlation with OSx VLV1 Attributes

OSx Attribute	OSx Command Form Data Written to Controller	OSx Status Bit Data Read from Controller [1]	APT Extension [2]
Override P/C Memory Location: C of Length 1	-32768 (Disable)	8 = 1	VSx.**OVRD** = 1
Mode_Cmd P/C Memory Location: C of Length 2	-32768 (Disable) 16384 (Lock) 0 (Unlock)	11 = 1 10 = 1 10 = 0	VSx.**DSBLD** = 1 VSx.**LOCKD** = 1 VSx.**LOCKD** = 0
Setpoint PC Memory Location: C of Length 1	-32768	9 = 1	VSx.**MOPEN** = 1
Timeout_1 [3] P/C Memory Location: TCP	Integer × 0.1 sec	Not implemented in OSx status word	VSx.**OTCP**
Timeout_2 [3] P/C Memory Location: TCP	Integer × 0.1 sec	Not implemented in OSx status word	VSx.**CTCP**

1 Refer to Figure C-4.

2 VSx represents VSN, VSS, PSN or PSS.

3 For OSx the Timeout_1 and Timeout_2 attributes are reflected in the status word via the combination of the opened and closed bits, as shown below.

VLV1		
Opened	Closed	State
1	0	Opened
0	1	Closed
0	0	Travel

Translating Tags for OSx/PCS VLV2

The OSx VLV2 corresponds to the APT VSD, VDD, VMD, and VUD valve types, CYL and CUD cylinder types, and PSD, PDD and PMD press types. Figure C-5 shows the VLV2 status word.

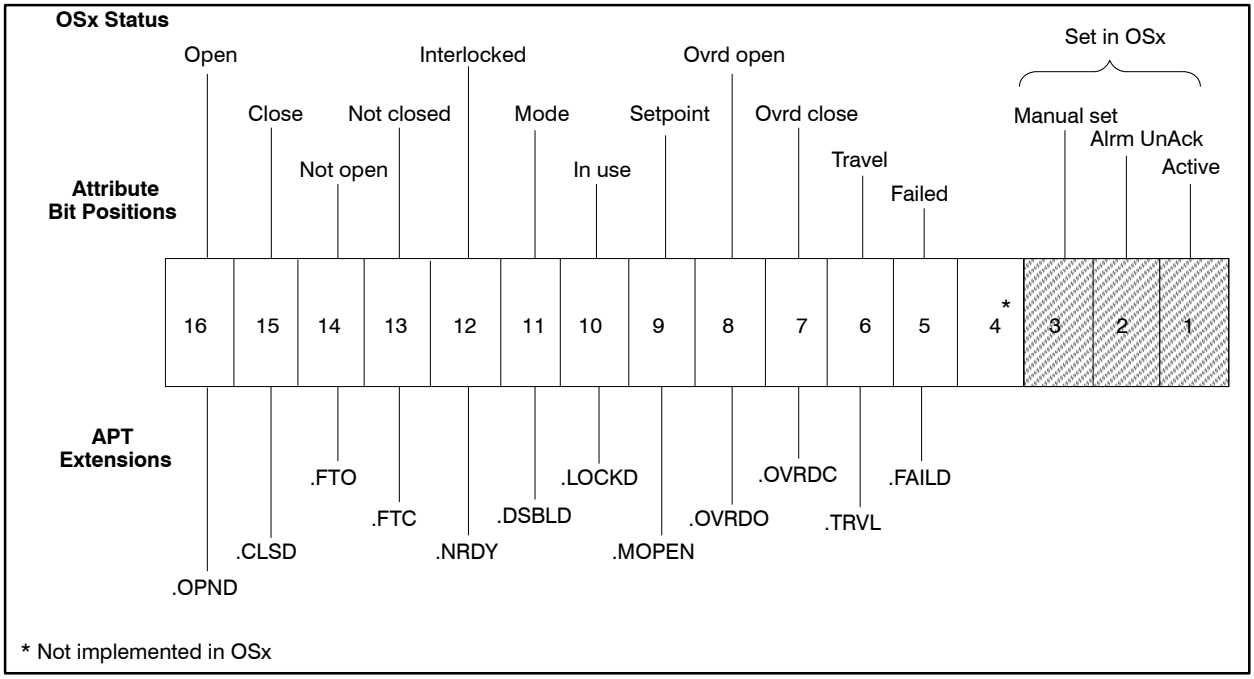

Figure C-5 APT Tag Correlation with OSx VLV2

Table C-13 shows the APT extension correlation with OSx VLV2 attributes.

Table C-13 APT Tag Correlation with OSx VLV2 Attributes

OSx Attribute	OSx Command Form Data Written to Controller	OSx Status Bit Data Read from Controller [1]	APT Extension [2]
Override P/C Memory Location: C of Length 2	-32768 (Open) 16384 (Close) -16384 (Both) 0 (Neither)	8 = 1 7 = 1 8 = 1 7 = 1 8 = 0 7 = 0	Vxx.**OVRDO** = 1 Vxx.**OVRDC** = 1 Vxx.**OVRDO** = 1 Vxx.**OVRDC** = 1 Vxx.**OVRDO** = 0 Vxx.**OVRDC** = 0
Mode_Cmd P/C Memory Location: C of Length 2	-32768 (Disable) 16384 (Lock) 0 (Unlock)	11 = 1 10 = 1 10 = 0	Vxx.**DSBLD** = 1 Vxx.**LOCKD** = 1 Vxx.**LOCKD** = 0
Setpoint PC Memory Location: C of Length 1	-32768	9 = 1	Vxx.**MOPEN** = 1
Timeout_1 [3] P/C Memory Location: TCP	Integer × 0.1 sec	Not implemented in OSx status word	Vxx.**OTCP**
Timeout_2 [3] P/C Memory Location: TCP	Integer × 0.1 sec	Not implemented in OSx status word	Vxx.**STCP**

1 Refer to Figure C-5.

2 Vxx represents VSD, VDD, VMD, or VUD.
For the cylinder, the override extensions are Cxx.**OVRDE** and Cxx.**OVRDR.** The setpoint extension is Cxx.**MEXTEND**.
The timeouts are Cxx.**ETCP** and Cxx.**RTCP**.

3 For OSx the timeout_1 and timeout_2 attributes are reflected in the status word via the combination of the opened and closed bits, as shown below.

VLV2		
Opened	Closed	State
1	0	Opened
0	1	Closed
0	0	Travel
1	1	Failed

I/O

The OSx tag type and the corresponding I/O types are listed in Table C-14.

When you translate values that are defined with a high and low range, the low range cannot be greater than the value that you enter in the form.

When you translate a digital output, the command and status of the translated tag both have the same controller address. For example, for a sensor or controller, if the address of a digital output is Y8, the address of both the status and command for that point is also Y8. For an S5 controller, if the address of a digital output is Q8.0, the address of both the status and command for that point is placed in a data word in DB or DX.

Table C-14 I/O

OSx Type	I/O Type	Descriptor
calc [1]	AI (Analog Input)	Analog Input
ao	AO (Analog Output)	Analog Output
ivar	BI (Binary-coded Decimal Input)	Integer Word
ivar	BO (Binary-coded Decimal Output)	Integer Word
di	DF (Digital Flag)	Digital Flag
di	DI (Digital Input)	Digital Input
do	DO (Digital Output)	Digital Output
calc [1]	RT (Resistance Temperature Detector) [2]	RTD Input
calc [1]	TC (Thermocouple) [3]	TC Input
ivar	WI (Word Input)	Word Input
ao	WO (Word Output)	Word Output

1 The .**RAW** extension can be translated as a OSx ai type (Series 505 only).
2 The maximum low range an RTD is 15.
3 The maximum low range for a TC is 900.

Declarations

The OSx tag type and the corresponding declaration types are listed in Table C-15.

When you translate a boolean, the command and status of the translated tag both have the same controller address. For example, for a Series 505 controller, if the address of a boolean is C9, the address of both the status and command for that point is also C9. For an S5 controller, if the address of a boolean is F9.0, the address of both the status and command for that point is placed in a data word in DB or DX.

Table C-15 Declarations

OSx Type	Declaration Type	Descriptor
do	B (Boolean)	Boolean
do	BA (Boolean Array) [1]	Boolean
di	F (APT Flag)	Read-only Boolean
ivar	I (Integer)	Calculated Integer
ivar	IA (Integer Array) [1]	Integer Array
calc	R (Real)	Calculated Float
calc	RA(Real Array) [1]	Calculated Float
ivar	SA (Sequence Array) [1]	Seq. Table Array
di10	IX (Boolean Array)	Boolean Array (length 10)
do10	DX (Boolean Array)	Boolean Array (length 10)
ao	SI (Scaled Integer)	Calculated Integer
ivar	SR (Shift Register Array) [1]	Shift Register Array
text	T (Text)	Text Tag
text	TA (Text Array) [1]	Text Array

[1] You must translate each array element individually.

⚠ WARNING

Boolean array of two elements long must not have the second array element marked for translation to OSx.

Marking the second array element for translation will cause an overwrite of the boolean location immediately following the array, which could cause unpredictable operations that could result in death or serious injury and/or damage to equipment.

You must either fully understand the consequences of marking the second array element, or declare a three-element boolean array instead.

Both APT declaration timers (Fast Timer and Slow Timer) have preset and current values that correspond to the OSx timer types. The Enable and Reset control bits are translated like a boolean or DO variable. Table C-16 lists the extensions that are translated for both timers.

Table C-16 Declaration Timers

OSx Type	Extension	Descriptor
tmr	*timer name (no extension)*	Timer Value
do	**.ENABL**	Timer Enable
do	**.RESET**	Timer Reset

Declaration counters have preset and current values that correspond to the OSx counter type. The Input and Enable control bits are translated like a boolean or DO variable. Table C-17 lists the extensions that are translated for counters.

Table C-17 Declaration Counters

OSx Type	Extension	Descriptor
ctr	*counter name (no extension)*	Counter Value
do	**.INPUT**	Counter Input
do	**.ENABL**	Counter Enable

Recipes

The OSx tag type and the corresponding recipe types are listed in Table C-18.

When you translate a recipe, APT translates the elements to OSx as normal integers, boolean entities, etc. The default tag name is a ***recipe_name.RECIPE.ELEMENT*** name. APT builds an area with all the elements as components of the area. See Chapter 1 for a description of how to use recipes with OSx.

Table C-18 Recipes

OSx Type	Recipe Extension Type	Area Component
area	*Recipe name (no extension)*	——
do	**.INUSE** (Boolean)	Command
area	**.HOLDREQ** [2]	Command
area	**.RECREQ** [2]	Command
do	B (Boolean)	Value
do	BA (Boolean Array) [1]	Value
ivar	I (Integer)	Value
ivar	IA (Integer Array) [1]	Value
calc	R (Real)	Value
calc	RA(Real Array) [1]	Value
area	**.SCALE** [2]	Value

[1] You must translate each array element individually.

[2] You must create these extensions on the Recipe form; they are not among the default extensions. They become attributes of the Area tag.

C.2 CFB Extensions

Advanced Blocks

The OSx tag type and extensions for the advanced blocks are listed in Table C-19 through Table C-23.

Table C-19 Dead Time Compensator

OSx Type	APT Extension	Descriptor
loop	*CFB name (no extension)*	PID loop
do	**.NRDY**	Interlock bit
ivar	**.AWS**	External windup status
calc	**.HLIM**	Output high limit
calc	**.LLIM**	Output low limit
calc	**.GAIN**	Dynamic block's gain term
calc	**.TAU1**	Dynamic block's time constant
calc	**.TAU2**	Dynamic block's time constant
calc	**.DT**	Dynamic block's dead time

Table C-20 Feedforward Output Adjust

OSx Type	APT Extension	Descriptor
loop	*CFB name (no extension)*	PID loop
do	**.NRDY**	Interlock bit
ivar	**.AWS**	External windup status
ivar	**.FMODE**	Feedforward status
calc	**.SOUT**	Feedforward iutput
calc	**.HLIM**	Output high limit
calc	**.LLIM**	Output low limit
calc	**.GAIN**	Dynamic block's gain term
calc	**.TAU1**	Dynamic block's time constant
calc	**.TAU2**	Dynamic block's time constant
calc	**.TLEAD**	Dynamic block's lead time constant
calc	**.DT**	Dynamic block's dead time

Table C-21 Feedforward Setpoint Adjust

OSx Type	APT Extension	Descriptor
loop	*CFB name (no extension)*	PID loop
do	**.NRDY**	Interlock bit
ivar	**.AWS**	External windup status
calc	**.MTHI**	Math in
calc	**.MTHO**	Math out
calc	**.HLIM**	Output high Limit
calc	**.LLIM**	Output low Limit
calc	**.GAIN**	Dynamic block's gain term
calc	**.TAU1**	Dynamic block's time constant
calc	**.TAU2**	Dynamic block's time constant
calc	**.TLEAD**	Dynamic block's lead time constant
calc	**.DT**	Dynamic block's dead time

Table C-22 Ratio Station

OSx Type	APT Extension	Descriptor
loop	*CFB name (no extension)*	PID loop
do	**.NRDY**	Interlock bit
ivar	**.AWS**	External windup status
calc	**.RSP**	External ratio setpoint
calc	**.OFFST**	Ratio offset
calc	**.RATIO**	Computed ratio
calc	**.HLIM**	Output high limit
calc	**.LLIM**	Output low limit

Table C-23 Dual Mode

OSx Type	APT Extension	Descriptor
loop	*CFB name (no extension)*	PID loop
do	**.NRDY**	Interlock bit
ivar	**.AWS**	External windup status
ivar	**.DMODE**	Dual mode status
calc	**.HLIM**	Output high limit
calc	**.LLIM**	Output low limit
calc	**.PSET**	Dual mode preset
calc	**.DLY1**	Dual mode delay 1
calc	**.DLY2**	Dual mode delay 2

Dynamic Blocks

Table C-24 lists the OSx tag and extensions for these dynamic blocks: second order lead lag, second order lag, first order lead lag, first order lag, and dead time delay.

Table C-24 Dynamic Blocks (Group 1)

OSx Type	APT Extension	Descriptor
do	.ENABL	Block control bit
di	.ENABLD	Block status
calc	.INPUT	Input (float)
ivar	.IINPUT	Input (integer)
calc	.OUT	Output (float)
ivar	.IOUT	Output (integer)
calc	.GAIN	Gain term
calc	.DTIME	Dead time
calc	.TLEAD	Lead time constant
calc	.TAU1	First time constant
calc	.TAU2	Second time constant
calc	.OUTIC	Initial output condition

Table C-25 lists the extensions for the integrator and the derivative dynamic blocks.

Table C-25 Dynamic Blocks (Group 2)

OSx Type	APT Extension	Descriptor
do	.ENABL	Block control bit
di	.ENABLD	Block status
calc	.INPUT	Input (float)
ivar	.IINPUT	Input (integer)
calc	.OUT	Output (float)
ivar	.IOUT	Output (integer)
calc	.GAIN *	Gain term
calc	.DTIME *	Dead time
* Not available for the derivative blocks.		

Limiter Blocks

The OSx type for each limiter block APT extension is listed in Table C-26 and Table C-27.

Table C-26 Output Limiter

OSx Type	APT Extension	Descriptor
do	.ENABL	Block control bit
calc	.OUTPUT	OUTPUT
calc	.INPUT	INPUT
calc	.HLIM	Input maximum
calc	.LLIM	Input minimum

Table C-27 Rate Limiter

OSx Type	APT Extension	Descriptor
do	.ENABL	Block control bit
calc	.OUTPUT	OUTPUT
calc	.INPUT	INPUT
calc	.RLIM	Rate-of-change limiter

Math Blocks

Table C-28 lists the OSx tag and extensions for the math CFB.

Table C-28 Math CFB Extensions

OSx Type	APT Extension	Descriptor
do	.ENABL	Block control bit
di	.ENABLD	Block status
calc	.OUTE	OUTPUT_E
calc	.OUTF	OUTPUT_F
calc	.OUTG	OUTPUT_G
calc	.OUTH	OUTPUT_H
calc	.INA	INPUT_A
calc	.INB	INPUT_B
calc	.INC	INPUT_C
calc	.IND	INPUT_D

Table C-29 lists the OSx tag and extensions for the following math CFB types: summer, subtractor, multiplier, and divider.

Table C-29 Math Blocks (Group 1)

OSx Type	APT Extension	Descriptor
calc	.OUT	OUTPUT (float)
ivar	.IOUT	OUTPUT (integer)
calc	.IN1	INPUT_A (float)
ivar	.IIN1	INPUT_A (integer)
calc	.IN2	INPUT_B (float)
ivar	.IIN2	INPUT_B (integer)

Table C-30 lists the OSx tag and extensions for the following math CFB types: square, square root, and absolute value.

Table C-30 Math Blocks (Group 2)

OSx Type	APT Extension	Descriptor
calc	.OUT	OUTPUT (float)
ivar	.IOUT	OUTPUT (integer)
calc	.IN	INPUT (float)
ivar	.IIN	INPUT (integer)

Other Blocks

The OSx types for the anti-reset windup, scale, and correlated lookup table block APT extensions are listed in Table C-31 through Table C-34.

Table C-31 Anti-Reset Windup (Constraint Type)

OSx Type	APT Extension	Descriptor
do	.ENABL	Block control bit
calc	.HLIM	High constraint
calc	.LLIM	Low constraint

Table C-32 Anti-Reset Windup (Select Type)

OSx Type	APT Extension	Descriptor
do	.ENABL	Block control bit

Table C-33 Scale

OSx Type	APT Extension	Descriptor
do	.ENABL	Block control bit
calc	.OUT	OUTPUT
calc	.IN	INPUT
calc	.HRIN	Input's high limit
calc	.LRIN	Input's low limit
calc	.HROUT	Output's high limit
calc	.LROUT	Output's low limit

Table C-34 Correlated Lookup Table

OSx Type	APT Extension	Descriptor
do	.ENABL	Block control bit
calc	.OUT	OUTPUT (float)
calc	.IN	INPUT (float)
ivar	.IOUT	OUTPUT (integer)
ivar	.IIN	INPUT (integer)

Selector Blocks

The OSx type for each selector block APT extension is listed in Table C-35 through Table C-40.

Table C-35 Average Selector

OSx Type	APT Extension	Descriptor
do	.ENABL	Block control bit
ivar	.POS	Selected input
calc (Series 505) ivar (S5)	.STAT	Number of inputs used
calc	.TVAL	Accepted tolerance
calc	.OUT	OUTPUT
calc	.IN1	INPUT_A
calc	.IN2	INPUT_B
calc	.IN3	INPUT_C

Table C-36 High and Low Selector Blocks

OSx Type	APT Extension	Descriptor
do	.ENABL	Block control bit
ivar	.POS	Selected input
calc	.OUT	OUTPUT
calc	.IN1	INPUT_A
calc	.IN2	INPUT_B
calc	.IN3	INPUT_C
calc	.IN4	INPUT_D
ivar	.SW1	A_ENABLE
ivar	.SW2	B_ENABLE
ivar	.SW3	C_ENABLE
ivar	.SW4	D_ENABLE

Table C-37 Inswitch Selector

OSx Type	APT Extension	Descriptor
do	.ENABL	Block control bit
ivar	.POS	Selected input
calc	.OUT	OUTPUT
calc	.IN1	INPUT_A
calc	.IN2	INPUT_B
calc	.IN3	INPUT_C
calc	.IN4	INPUT_D

Table C-38 Median Selector

OSx Type	APT Extension	Descriptor
do	.ENABL	Block control bit
ivar	.POS	Selected input
calc	.OUT	OUTPUT
calc	.IN1	INPUT_A
calc	.IN2	INPUT_B
calc	.IN3	INPUT_C

Table C-39 Outswitch Selector

OSx Type	APT Extension	Descriptor
do	.ENABL	Block control bit
ivar	.POS	Selected input
calc	.IN	INPUT
calc	.OUT1	OUTPUT_A
calc	.OUT2	OUTPUT_B
calc	.OUT3	OUTPUT_C
calc	.OUT4	OUTPUT_D

Table C-40 Threshold Selector

OSx Type	APT Extension	Descriptor
do	.ENABL	Block control bit
calc	.IN	INPUT
di	.DOUT	DISCRETE OUTPUT
calc	.LIMIT	THRESHOLD LIMIT

Standard Blocks

The OSx tag types and extensions for the standard blocks are listed in Table C-41 through Table C-43.

Table C-41 PID

OSx Type	APT Extension	Descriptor
loop	*CFB name (no extension)*	PID loop
do	.NRDY	Interlock bit
ivar	.AWS	External windup status
calc	.HLIM	Output high limit
calc	.LLIM	Output low limit

Table C-42 On/Off

OSx Type	APT Extension	Descriptor
loop	*CFB name (no extension)*	PID loop
do	.NRDY	Interlock bit
ivar	.IOUT	Output

Table C-43 Analog Alarm

OSx Type	APT Extension	Descriptor
ai	*CFB name (no extension)*	Analog alarm block

Valve Control Blocks

The OSx type for each valve block APT extension is listed in Table C-44 through Table C-47.

Table C-44 Split Range

OSx Type	APT Extension	Descriptor
do	.ENABL	Block control bit
calc	.OUT1	OUTPUT1
calc	.OUT2	OUTPUT2
calc	.IN	INPUT
calc	.BRKP1	BREAK1
calc	.BRKP2	BREAK2

Table C-45 Valve Sequencer

OSx Type	APT Extension	Descriptor
do	.ENABL	Block control bit
calc	.OUT	OUTPUT (float)
ivar	.IOUT	OUTPUT (integer)
calc	.IN	INPUT
di	.DOUT	Valve relay
calc	.BRKPL	Opening hysteresis point
calc	.BRKPH	Closing hysteresis point

Table C-46 Proportional Time Control

OSx Type	APT Extension	Descriptor
do	.ENABL	Block control bit
di	.DOUT	OUTPUT
calc	.IN	INPUT
calc	.DUTY	Maximum ontime

Table C-47 Motor Position Control

OSx Type	APT Extension	Descriptor
do	.ENABL	Block control bit
calc	.PV	Process variable
calc	.SP	Process setpoint
calc	.DBAND	Dead zone

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